PROG. DEV.

HURRICANE SURVEY

INTERIM REPORT

WAREHAM-MARION

MASSACHUSETTS

APPENDICES

U.S. Army Engineer Division, New England
Corps of Engineers
Waltham, Mass.

25 October 1961

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GLOSSARY

HURRICANE SURGE: the mass of water causing an increase in the elevation of the water surface above predicted astronomical tide at the time of a hurricane; it includes wind setup; sometimes the maximum increase in elevation is referred to as the surge.

HURRICANE TIDE: the rise and fall of the water surface during a hurricane, exclusive of wave action.

KNOT: a velocity equal to one nautical mile (6080.2 feet) per hour (about 1.15 statute miles per hour).

OVERTOPPING: that portion of the wave runup which goes over the top of a protective structure.

PONDING: the storage of water behind a dike or wall from local runoff and/or overtopping by waves.

POOL BUILDUP: the increase in elevation of water surface behind a structure due to runoff and/or overtopping by waves.

RUNUP: the rush of water up the face of a structure on the breaking of a wave. The height of runup is measured from the stillwater level.

SIGNIFICANT WAVE: a statistical term denoting waves with the average height and period of the one-third highest waves of a given wave train.

SPRING TIDE: a tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

STANDARD PROJECT HURRICANE: a storm that may be expected from the most severe combination of meteorologic conditions that are considered reasonably characteristic of the region involved, excluding rare combinations.

STILLWATER LEVEL: the elevation of the water surface if all wave action were to cease.

STORM SURGE: same as "hurricane surge".

WAVE HEIGHT: the vertical distance between the crest and the preceding trough.

GLOSSARY (cont'd.)

WAVE TRAIN: a series of waves from the same direction.

WIND SETUP: the vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water.

APPENDIX A

HISTORY OF HURRICANE AND OTHER STORM OCCURRENCES

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HISTORY OF HURRICANE OCCURRENCES

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HISTORY OF HURRICANE OCCURRENCES

A-1. GENERAL

A review has been made of historical data on past hurricanes that have struck or threatened the south coast of New England in order to determine the possibility of future hurricane occurrences in the Buzzards Bay area, including Wareham and Marion, Massachusetts. Since the Buzzards Bay area lies in the path of hurricanes moving into New England from the south, it has frequently borne the brunt of these storms. The records indicate that the area has experienced or has been threatened by hurricane tidal flooding upon 69 occasions from 1635 to date. The greater number of these hurricanes, owing to the locations of their paths, did not cause any tidal flooding in the survey area. However, they did present a potential threat of such flooding. The ten hurricanes which have created the greatest tidal flooding in the Buzzards Bay area, as far as can be determined from existing records, are listed below in their estimated order of magnitude.

August 3, 1638	December 10, 1878
August 15, 1635	October 30, 1866
September 21, 1938	September 8, 1869
August 31, 1954	October 23, 1878
September 23, 1815	September 14, 1944

The two earliest hurricanes of record, namely those of August 1635 and August 1638, created flood levels apparently higher than the recent floods of 1938 and 1954, probably the greatest experienced in New England during the past 326 years. However, since the extent of flood damages is relative to the degree of development in the flooded area, these early hurricanes were not as damaging as the great hurricanes of the present century. The two earliest hurricanes of record, which according to historical accounts must have been very severe, occurred prior to the settlement of Wareham and Marion. The recurrence of these two hurricanes under present conditions would cause extensive damages, possibly in excess of the damages suffered in 1938 and 1954.

A-2. SUMMARY OF HURRICANE OCCURRENCES

A summary has been prepared, see Table A-1, which lists all hurricanes known to have directly affected the Buzzards Bay area, and, also, all hurricanes known to have threatened the area. In the latter case, a slight change in meteorological conditions could have caused any of these hurricanes to follow a course more critical to the area under study, thereby subjecting the area to tidal flooding. In several instances, where there are early records of a great storm striking the coast of Connecticut and Rhode Island, it has been assumed that the storm affected the Buzzards Bay area. The following classifications indicate the effect of the recorded hurricane occurrences on the survey area:

Type "A": Hurricanes causing severe tidal flooding.

Type "B": Hurricanes causing damage from wind and rainfall (usually accompanied by high seas and moderate tidal flooding.)

Type "C": Hurricanes threatening the area.

Of the 69 hurricanes of record that either hit or narrowly missed striking the Buzzards Bay area, as listed in Table A-1, 12 are of type "A," 23 of type "B," and the remaining 34 of type "C". Forty-three of the listed hurricane experiences (3 type "A," 13 type "B," and 27 type "C") have occurred during the period from 1901-1960. The fact that there is a record of 43 hurricanes in this 60-year period, as compared with 26 in the 266-year period from 1635-1900, is not considered indicative of an increase in hurricane activity in recent years, but of a lack of records and information on storms prior to 1900.

TABLE A-1

HISTORICAL HURRICANES

Buzzards Bay Area, Massachusetts

Including Wareham and Marion

Date of Hurricane	Category (1)	Source of Data	Remarks
1635, Aug.15	A	(2)(3)	Great tidal surge; height of tidal flooding may have exceeded that of Sept.1938.
1638, Aug. 3	A	(3)	Historical account indicates greatest tidal flooding ever experienced along Mass. and R.I. coast.
1723, Oct. 30	A	(3)	Very high tides in R.I.; considerable damage.
1757, June 30	C	(2)	Atlantic Coast hurricane, Florida to Boston, Mass.
1761, Oct. 24	A	(3)	Very high tides in Narragansett Bay, R.I.; reports of much damage from wind and water.
1770, Oct.19-20	A	(3)	A violent storm; immense loss of life and property along the coast.
1773, Aug. 19	C	(2)	Passed near Boston, Mass. No record of damages in Buzzards Bay area.
1787, Sept. 19	C	(3)	Reports of damage at Stamford and Norwalk, Conn. No report of damage along Mass. coast.
1788, Aug. 19	B	(2)(3)	Affected western New England; much damage in Conn.and Mass.
1804, Sept.8-9	C	(2)	Severe storm; passed over Cape Cod, travelling northeast.

(Footnotes are at end of Table.)

TABLE A-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1804, Oct. 9-10	B	(2)(3)	Reports of wind and rain damage along Mass. and R.I. coast.
1815, Sept. 22-23	A	(2)(3)	Tide rose a reported 10 feet above high water at New Bedford on the 23rd.
1821, Sept. 3	B	(2)(3)	Wind damage; no unusual rise in tide in Buzzards Bay. Intensity of storm hit New York.
1829, July 24	C	(2)(3)	Reported to have been felt in Boston, Mass.; no accounts of damage in Buzzards Bay area.
1841, Oct. 2-3	B	(2)(3)	Reports of wind damage. Path was probably near Nantucket.
1854, Sept. 10-11	C	(2)	Severe in southern states; passed over New England, near Boston.
1866, Oct. 29-30	B	(2)(3)	Unusually high tide; submerged several wharves.
1869, Sept. 8	A	(2)(3)	Tide rose to level of wharves, much damage.
1877, Oct. 4-5	B	(2)(3)	Path was south of Long Island and Nantucket. Reports of wind and rain damage.
1878, Oct. 22-23	A	(2)(3)	Destructive storm along the coast. Wharves at New Bedford flooded; heavy rain.

TABLE A-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1878, Dec. 10	A	(3)	Wharves at New Bedford covered by tide; gale winds. Reported as highest tide since 1869 gale.
1879, Aug. 18	C	(2)	Path followed up coast, passed over Cape Cod. No account of damage along Mass. coast.
1889, Sept. 10	B	(2)(3)	Accounts of high tides and waves at Newport, R.I.
1893, Aug. 23-24	B	(2)(3)	Storm caused wind, rain and tidal-flooding along south coast of New England.
1893, Aug. 29	B	(2)(3)	Storm passed west of New York City, crossed central Maine, moving northeast. Reports of high tides and surf along Conn. coast.
1896, Sept. 9-10	B	(2)(3)	Torrential rain and hurricane winds. Reports of tidal flooding along R.I. coast.
1901, Sept. 19	C	(2)(4)	Passed south and east of Cape Cod, traveling northeast.
1902, June 16-17	C	(2)(4)	Path crossed Buzzards Bay and Cape Cod, moving northeast; no accounts of damage in Buzzards Bay area.
1902, June 29-30	C	(2)	Center passed over Conn. and southern R.I., traveling southeast; no accounts of damage in Buzzards Bay area.
1902, Oct. 12	C	(2)(3)(4)	Storm followed path south of Long Island and Nantucket, moving east. Reports of heavy rain and high wind at New Haven, Conn.

TABLE A-1 (Cont 'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1903, Sept. 16	C	(2)(3)	Storm crossed northeastern Pa., moving northwest. No records of damage along Mass. coast.
1904, Sept. 15	B	(2)(3)	Center passed over northeastern Conn., moving northeast. Local wind damage.
1904, Nov. 13	C	(2)(4)	Passed south of Nantucket, moving northeast. No reports of damage along Mass. coast.
1911, Sept. 1	C	(2)	Passed south of Cape Cod. No accounts of damage along Mass. coast.
1912, Sept. 16	C	(2)	Passed near New Bedford; followed easterly path across southern New England.
1916, July 21	C	(2)(4)	Passed off east end of Cape Cod, heading northeast. No accounts of damage along Mass. coast.
1920, Sept. 30	B	(2)(4)	Storm passed just west of New York, heading north. Reports of wind and high water damage along Conn. coast,and at Boston.
1923, Oct. 19	C	(2)(4)	Passed near Boston, moving northwest. Storm of slight energy.
1924, Aug. 26	B	(2)(3)	Crossed tip of Cape Cod, moving northeast. Some damage from strong winds and heavy rain.
1929, Oct. 2	C	(2)(4)	Moved northeast, passing over eastern New York and northwestern Vermont. Reports of high tide damage along Conn. coast; no reports of damage along Mass. coast.

Date of Hurricane	Category (1)	Source of Data	Remarks
1933, Aug. 23-24	C	(2)(3)	Storm moved across western New York and down St. Lawrence River. Driving rain and high tides along Conn. coast. No reports of damage along Mass. coast.
1933, Sept. 16-17	B	(2)(3)	Passed south of Cape Cod, moving northeast; heavy seas and rain in New Bedford area.
1934, June 19	C	(2)	Traveled overland from Louisiana; crossed Long Island and Cape Cod, moving northeast.
1934, Sept. 9	B	(2)(4)	Crossed Long Island and central Conn., moving north.
1936, Sept. 19	B	(2)(3)(4)	Passed south of Nantucket, heading northeast; high seas; wind and rain damage.
1938, Sept. 21	A	(2)(3)(4)	Most damaging storm to strike southern New England. Surge 11.1 feet at Wareham caused flooding to 14.2 feet msl, 11.8 feet above mhw.
1940, Sept. 2	B	(2)(3)(4)	Passed south of Nantucket, heading northeast; strong winds caused minor damage.
1940, Sept. 16	C	(2)(4)	Followed northeasterly path east of Cape Cod. No accounts of damage.
1943, Oct. 17	C	(2)(4)	Passed east of Cape Cod, moving due north. No accounts of damage.
1944, Aug. 3	C	(2)(4)	Moved northeasterly along path south of Long Island and Nantucket. No accounts of damage.

TABLE A-1 (Cont'd)

Date of Hurricane	Category(1)	Source of Data	Remarks
1944, Sept.14-15	A	(2)(3)(4)	Center passed over Providence, R.I. and south of Boston, Mass. Surge of 10.5 feet at Wareham, caused flooding to 9.5 feet,msl.
1944, Oct. 21	C	(2)(4)	Path crossed over Nantucket and tip of Cape Cod. No accounts of damage.
1945, June 26	C	(2)(3)(4)	Followed northeasterly path from Florida to Nova Scotia, passing south of Nantucket.
1945, Sept. 19	C	(2)(4)	Overland from Florida; passed just west of New York, moving northeast.
1949, Aug. 29	C	(2)(3)(4)	Traveled overland from northern Florida, crossed center of Maine.
1950, Aug. 20	C	(2)(3)(4)	Passed south of Nantucket, heading generally north-east; strong winds at Cape Cod. No reports of local damage.
1950, Sept. 11	B	(2)(3)(4)	Passed south and east of Nantucket, then headed east. Reports of minor damage from wind and seas at New Bedford.
1952, Sept. 1 ("Able")	C	(2)(3)(4)	Followed northeasterly track, approximately over New York.
1953, Aug. 15 ("Barbara")	C	(2)(3)(4)	Followed path south of Long Island and Nantucket.
1953, Sept. 7 ("Carol")	C	(2)(3)(4)	Passed east of Cape Cod heading generally north.
1954, Aug. 31 ("Carol")	A	(2)(3)(4)	Second most damaging storm to hit Buzzards Bay area. Crossed east end of Long Island moving north. Surge of 11.3 feet at Wareham caused flooding to 13.6 feet msl.

Date of Hurricane	Category (1)	Source	Remarks
1954, Sept. 11 ("Edna")	B	(2)(3) (4)	Passed over Cape Cod heading northeast. High seas, minor damage from wind in Buzzards Bay area.
1954, Oct. 15 ("Hazel")	B	(2)(3) (4)	Heavy rainfall and river flooding in the interior of Conn., Mass., and R.I.; negligible tidal flooding along coast. Center moved through western New York.
1955, Aug. 13 ("Connie")	C	(3)(4)	Caused scare in New England and heavy rainfall but no damage. Storm passed southwest of Washington, D.C.
1955, Aug. 18 ("Diane")	B	(2)(3)	Passed just south of Long Island and about over Nantucket. Brought record rainfall to many areas of New England.
1955, Sept. 20 ("Ione")	C	(3)(4)	Caused scare in New England but no reported damage. Storm turned east and then northeast after passing inland at Cape Hatteras.
1958, Aug. 29 ("Daisy")	C	(3)(4)	Caused scare in New England but no damage. South of Nantucket the storm turned east and then northeasterly.
1960, July 30 ("Brenda")	B	(3)(4)	Storm crossed coast just west of Bridgeport and continued into western Conn., and Mass. Some minor wind damage, negligible tidal flooding.

TABLE A-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1960, Sept. 12 ("Donna")	B	(3)(4)	Storm crossed coast near New London, Conn., continued northeastward between Worcester and Boston, Mass., and into N.H. Tides 4 to 5 feet above normal along southern coast of New England caused flood damages at a number of localities.

Notes

(1) The following assigned categories pertain to the effect of a hurricane on the Buzzards Bay area, Mass.
- A: Caused severe tidal flooding.
- B: Caused damage from wind or rainfall (usually accompanied by high seas and moderate tidal flooding.)
- C: Threatened area.

(2) "Hurricanes - Their Nature and History," by I.R. Tannehill (1956).

(3) Local newspaper accounts, histories, etc.

(4) Material furnished by U.S. Weather Bureau.

A-3. DESCRIPTIONS

Brief descriptions of type "A" and type "B" hurricanes experienced in the Buzzards Bay area prior to 1930, as recorded by historians and as reported in newspaper accounts and other records, are given below. Subsequent to 1930, numerous and more adequate records are available of storm occurrences, including data on tidal-flood levels, wind velocities, and other storm characteristics.

a. 15 August 1635. (Type "A") From: "Of Plymouth Plantation, 1620-1647," by William Bradford.

> "This year the 14 or 15 of August (being Saturday) was such a mighty storm of wind and rain, as none living in these parts either English or Indian, ever saw, being like (for the time it continued) to those Hauricanes and Tuffons that writers make mention of in the Indies. It began in the morning, a little before day, and grew not by degrees, but came with violence in the beginning to the great amazement of many. It blew down sundry (211) houses, and uncovered others; divers vessels were lost at sea, and many more in danger. It caused the sea to swell (to the southward of this place) above 20 feet, right up and down, and made many of the Indians to climb into trees for their safety; it took off the board roof of a house which belonged to this plantation at Manamet, and floated it to another place, the posts still standing in the ground; and if it had continued long without the shifting of the wind, it is like it would have drowned some part of the country. It blew down many hundred thousands of trees, turning up the stronger by the roots, and breaking the higher pine trees off in the middle, and the tall young oaks and walnut trees of good bigness were wound like a withe, very strange and fearful to behold. It began in the southeast and parted toward the south and east, and veered sundry ways; but the greatest force of it here was from the former quarters. It continued (not in the extreme) above 5 or 6 hours, but the violence began to abate. The signs and marks of it will remain this 100 years in these parts where it was sorest. The moon suffered a great eclipse in the second night after it."

From: "The History of New England from 1630 to 1649," by John Winthrop.

> "...This tempest was not so far as Cape Sable, but to the south more violent, and made a double tide all that coast...
>
> "The tide rose at Narragansett fourteen feet higher than ordinary and drowned 8 Indians flying from their wigwams."

b. 3 August 1638. (Type "A") From: "The History of New England from 1630 to 1649," by John Winthrop.

"In the night was a very great tempest or hiracano at S.W. which drave a ship on ground at Charlestown, and brake down the windmill there, and did much other damage. It flowed twice in 6 hours and about Narragansett it raised the tide 14 or 15 feet above the ordinary spring tides upright."

c. 30 October 1723. (Type "A") From: "The Boston News-Letter, No. 1032. From Thursday, October 31, to Thursday, November 7, 1723."

"Rhode Island, November 1 ...
"...On Wednesday last we had here a very great South East storm of Wind & Rain, and a very high Tide, a Foot higher than ever was known before, which has broken & carried away several of our Wharffs, and drove some vessels ashore from their anchors and was done considerable damage in Warehouses and Cellars, to dry goods, and other merchandize: the Loss is computed to some thousand pounds..."

d. 24 October 1761. (Type "A") From: "The Boston News-Letter No. 2991. Thursday, October 29, 1761."

"Last Friday evening between 8 and 9 o'clock came on the severest N.E. Storm of Wind and Rain that has been known here for 30 Years past, and continued "till between 2 and three o'Clock next Morning;...Five or six Vessels were drove ashore at Providence in Rhode Island Government, and greatly damag'd, and it being high Water there it got into the Stores and Cellars and damag'd Sugars &c. to the amount of 12 or 15,000 (pounds) their Currency; it has also entirely carried away the great Bridge at that Place. - On both roads East & West, so far as we have heard, the Roofs of Houses, Tops of Barns, and Fences, have been blown down, and it is said Thousands of trees have been torn up by the Roots by the violence of the above storm, and we fear we shall hear melancholy Accounts of Damage done at Sea."

From: "The Newport Mercury."

"On Friday last came on a terrible storm from the Northeast, which continued increasing with a very heavy rain, and did not abate till after 2 in the morning. The violence of the wind broke off part of the steeple of Trinity Church. Several persons sustained considerable loss in their sugar, salt, etc. by the prodigious rise of tide, which flowed into their stores and cellars. Many of the ships in the harbor were driven ashore from the wharves and their moorings, but without any considerable damage except to two ships. Sad havoc has been made with the lumber and wood on the wharves, great quantities of fence blown down and numbers of trees torn up by the roots. People hardly thought themselves safe in their own houses, for a more violent storm has scarce ever been known here."

e. 19-20 October 1770. (Type "A") From: "History of the State of Rhode Island," by Samuel Greene Arnold.

"A violent storm again blew down a part of the spire of Trinity Church at Newport, and caused an immense loss of life and property along the coast. Newport suffered very severely in this gale."

f. 19 August 1788. (Type "B"). From: the diary of William Wheeler in "Black Rock, Seaport of Old Fairfield, Connecticut. 1699-1870."

"The hardest gale that has been for many years--- at 1 o'clock a Sloop & Schooner went on shore---. The Gale reached 100 miles up country, in some places shifting from SE to NW & twisting of trees 9 inches in diameter---- it moved Carson's house about 6 feet."

From: "The New Haven Gazette and the Connecticut Magazine," Thursday, August 21, 1788.

"New Haven

"Last Tuesday morning came on a violent gale of wind from the South, which at about one o'clock P.M. veered to S.S.W. and blew a perfect hurricane.

"Several vessels were drived ashore and very material damage is done to the long Wharf...We expect to hear of much damage done at sea and in the harbours on our coast...."

From: "The Connecticut Courant and Weekly Intelligence," Monday, August 25, 1788.

"New Haven, Aug. 20.

"Yesterday we had a violent gale of wind, the height of which was from the S.E. about one o'clock. Though the tide was not full as has been frequent in easterly storms, considerable damage was done to the Long Wharf by the violence of the waves and several vessels parted their masts, but the shipping received no material damage. The Indian corn is much injured and the trees stripped of their fruit and some apple trees blown down."

g. 9-10 October 1804. (Type "B") From: "Boston Gazette," Thursday, October 11.

"Boston - On Tuesday morning last, a most violent storm commenced in this place, and continued its destructive career, until about 5 o'clock Wednesday morning. The wind blew at first from South-Southeast then shifted to East increasing its power until about 3 o'clock when it abated for a few moments, and then veered to Northeast. From this quarter, the gale blew with a violence and fury unprecedented in the annals of this town. The damage which has been sustained by this tremendous hurricane, can not at present be eliminated, but is very great and extensive.

From: "Boston Gazette," Thursday, October 18.

"The Late Storm - To the particulars of the late gale, which it has been our painful duty to state, in previous papers, we have now to add..... At Providence (R.I.), the gale was severely felt, several vessels were driven from their moorings to the shore. At Newport, also considerable damage was done to the shipping and to the houses in that town."

h. 22-23 September 1815. (Type "A") From: "History of New Bedford and Its Vicinity" by Leonard Bolles Ellis.

"On Saturday morning, September 29 (sic) (23) 1815, New Bedford was visited by a tremendous gale, that for violence and disaster has never been equaled in the history of the town. The gale began early in the day and continued with great violence till midday. The tide rose 10 feet above high water mark, and 4 feet higher than ever was reached before. So rapid was its rise that the occupants of stores and warehouses along the river front were compelled to leave them hurriedly.

"Salt works carried away, shops wholly or partially destroyed, several dwelling houses were blown down, all the wharves were injured and some of them ruined, 16 vessels were blown adrift and thrown ashore."

i. <u>3 September 1821.</u> (Type "B") From: "The Newport Mercury."

" During the severe gale on Monday night, the Brig Commerce got loose from her fastening at one of the wharves near the Market, and came with a tremendous crash against the bridge, slightly injuring some small craft which lay in her course, and the railing of the bridge. Considerable damage was done to trees, etc. in this vicinity by the gale; a part of Butts Rope Walk West Side, and an unfinished building at the North end, were blown down; the tower erected for the accomodation of the wild beasts (our annual commencement visitors) in the yard of Wessons Hotel, was also demolished but its inmates were secured from elopement.

"Much apprehension was entertained for several hours of disasters by flood as well as wind, and there were many waking eyes and throbbing hearts; but happily the tide and the residents within the range of the devastations by the never-to-be-forgotten flood of 1815 retired to their beds about midnight, providently delivered from a visitation fearfully anticipated, and dreaded equally with fire brands, arrows and death. The tide did not rise much above its usual bounds."

j. <u>2-3 October 1841.</u> (Type "B") From: "Daily Mercury," New Bedford.

"A severe northeasterly storm commenced here on Saturday night and continued on Sunday and yesterday with but a little abatement. Some damage was done to the shipping and many chimneys were blown down. A large unfinished stone building was blown entirely down, and one or two small houses destroyed."

k. <u>29-30 October 1866.</u> (Type "B") From: "Daily Mercury," New Bedford.

"The southeasterly which commenced on Monday morning and was accompanied during the night by rain blew a gale yesterday forenoon and the water fell in torrents. The tide was unusually high submerging several wharves and at one time nearly crossing Front Street. Several vessels were driven from their moorings by the gale and the rush of the water. Chimneys, fences, etc. were blown down. Telegraph wires were damaged. Railroad bridges were undermined. About 3:00 p.m. the gale had spent its force."

l. 8 September 1869. (Type "A") From: "History of New Bedford and Its Vicinity," by Leonard Bolles Ellis.

"On the 8th of September 1869, a destructive southeast gale swept over the city and vicinity. It began about 4:00 in the afternoon, increasing rapidly in force, and continued until about 7:00 p.m. The tide rose to the level of the wharves, and huge waves swept over them. Buildings were unroofed, fences blown down, trees uprooted, chimneys blown down; vessels strewn on both sides of the river, all more or less damages and some dismasted. A costly result of the gale was the destruction of the New Bedford and Fairhaven bridge."

From: "Norwich Morning Bulletin," Norwich, Conn., September 12.

"Storm (at Mystic, Conn.) worst since 1815. Came at low water and the tide, though rising higher than it has for 2 or 3 years, did less damage than it otherwise would have done."

m. 4-5 October 1877. (Type "B") From: "New Bedford Evening Standard."

"A severe storm of wind and rain commenced last night and continued through the night and day. Some of the rain came in sheets and the layers of sand which have washed down the lower streets attests the amount of rainfall.

"Limbs were broken off, fences blown down, walnuts and fruits blown from trees.

"More water than the drains could carry off ran from the Second Street gutter into the Robeson Building. Sycamore Street, between County and Summer, is badly gullied, the gutter having been obstructed by a private bridge which turned the current into the middle of the street.

"The damage along the water front is insignificant as ample notice was given by old indications and preparations made for the storm. Several vessels in the harbor dragged their anchor. On the north side of Fish Island some spars and a scow got loose.

"Capt. Joseph C. Delano's gauge indicated a rainfall of 3.2 inches."

n. 22-23 October 1878. (Type "A") From: "New Bedford Evening Standard."

"The storm yesterday afternoon and last night was very severe, the rain falling in torrents, but there was very little damage in this vicinity. Several vessels and boats got adrift at the docks,but trifling damage was done, some of the wharves were flooded. The last train from Providence was prevented from reaching Fall River on account of a washout near Cole's River. The velocity of the wind was 50 miles an hour. The storm originated in the Gulf of Mexico on Monday morning."

o. 10 December 1878. (Type "A") From: "New Bedford Evening Standard."

"The southeast storm of yesterday and last night was very severe, the rain falling copiously and the wind blowing a gale. The wharves were covered by the tide at 8:00 p.m. which was higher than since the great September gale of 1869. The rainfall in this city during the storm of Monday and yesterday (including the melted snow) was 1.56 inches."

p. 10 September 1889. (Type "B") From: "The Boston Daily Globe," Tuesday, September 10.

"New York, Tuesday, September 10 - Coney Island today is a scene of wrecks and desolation...The greatest tide that has ever been experienced struck the island at 6:00 o'clock this morning and increased in volume and fury along past 8:00 o'clock."

"Newport, Rhode Island, September 10. - The scene at the bathing beach and along the cliffs and south shore, caused by the heavy surf and high tide, is magnificent tonight. Each new high tide does a little more damage at the bathing beach. The roadbed is filled with stones, sand, and driftwood..... The waves dash over the cliff walk in places and the water is up to Benten's Reef life saving station."

From: "The Greenwich (Conn.) News," Friday, September 13.

"The furious northeaster which has been raging along the Atlantic coast for the past few days is one of the severest storms known in this vicinity for years, and one of the most destructive to property.

q. 23-24 August 1893. (Type "B") From: "New Bedford Evening Standard."

"Early last evening a shower fell in this city, and this was succeeded by a second one about 11:30 p.m. About 1:45 a.m. the wind began to rise and came from the southeast, reaching the force of a moderate gate, and at 6:00 a.m. had attained a velocity of 23 m.p.h. The wind at times came in gusts, lasting perhaps two minutes, when the velocity would reach 40 m.p.h. Rain accompanied the wind, falling heavily for several hours. Trees were blown down, chimneys blown over, trolley wires broken, etc. No serious damage was done to any vessels although they were tossed about. Water was blowing over the New Bedford and Fairhaven railroad."

r. 29 August 1893. (Type "B") From: "The Day," New London, Connecticut, Tuesday, August 29.

"The storm today has been free from some of the disagreeable accompaniments that made last Thursday's blow one of the worst experienced in this vicinity in recent years....

"The tide was very high all the morning, nearly up to the string pieces on the bulkheads and almost washing the timbers of the deck of the railroad bridge at the upper end of town.

"Down at Ocean Beach the scene today was grandeur, if possible, than last week. The surf was heavier and there was much more of it....."

s. 9-10 September 1896. (Type "B") From: "New Bedford Evening Standard."

"A storm began in this city between Tuesday night and Wednesday morning. All through Wednesday there were frequent heavy showers. During the afternoon the wind which all the time was from the northeast, increased to hurricane force and the weather bureau hoisted signals at this port giving warnings. The greatest force of the wind in this city was 45 miles an hour reached at 8:00 this morning, but the force has decreased considerably since. There is a peculiarity in regard to this hurricane in that it seems to have been confined on the land to a comparatively limited area, which would indicate that the hurricane had much of its force at sea and struck the coast at the east of New York City, passed over a tract of territory to the south of Boston and went off to sea again. In this city and vicinity the wind was heavy during the night and there was a continual downpour of rain, which kept up almost unceasingly this forenoon. The low lying region on South Water Street, between Howland and Grinell Streets, presented the usual flooded appearance which follows all heavy storms. The depth of water at some points was over two feet and stores on the line in many cases has to be closed. No serious damage to boats. Extra moorings put out. Three or four craft came ashore but were hauled up high and dry. Planking ripped off landing stage at fish wharf near Middle Street. The rainfall as registered at the water works pump house up to 11:00 a.m. today was 3.64 inches. The easterly blow raised sad havoc among the little pleasure craft anchored around Bare Kneed rocks at Nonquitt."

t. 15 September 1904. (Type "B") From: "The Morning Mercury," New Bedford.

"Yesterday's storm will probably pass as the September gale. The wind was recorded as blowing 40 miles an hour but it was of a cyclonic nature that twisted things badly. The wind blew from the southward until 8:00 when it whipped around and came out from the northwest and blew hard. The storm raged at its worst at about 6:30 and then the small yachts at anchor in the harbor suffered. A few vessels broke loose and suffered damage. Above the bridge, however, the wind and sea worked havoc with the small boats of the Apponegansett Boat Club. Nearly all of them broke from their moorings; some sunk, others damaged. The tide at Padanaram acted queerly and rose and fell three times during the day. The damage about the city to trees and buildings was considerable. Telephone and telegraph service was out of working order. The tide played queer tricks. At Merrill's wharf it was said that the tide dropped 8 inches in 5 minutes. The maximum velocity attained by the wind was 40 miles an hour."

u. 30 September - 1 October 1920. (Type "B") From: "The Daily Advocate," Stamford, Conn., October 1.

"New Haven, Oct. 1. Thousands of dollars of damage was done along the Sound last night by one of the worst storms in several years. Driven by a gale which exceeded 40 miles from the southwest and accompanied by a high tide. The waves rolled mountain high against the beach during the night, the tide reaching a record height about midnight. Many boats were washed ashore, cottages, piers and breakwaters being partially wrecked."

From: "The Boston Evening Globe," Friday, October 1.

"Sailing craft and power boats of all description were thrown up on the various beaches of South Boston in the terrific rain and wind storm of last night....The storm started about 10:00 p.m. in a strong Northeast wind, and about an hour later, while the tide was very rough, the wind made a sudden shift to the Southwest and increased in rate of speed.

"It was one of the most severe storms that has struck Center Point in years....Every year just about this time a big windstorm hits City Point,...."

v. 26 August 1924. (Type "B") From: "New Bedford Evening Standard."

"For nearly an hour yesterday the wind swept New Bedford streets at 60 miles an hour, the heaviest velocity on record since the gale of 1869. The high velocity began about 3:30 p.m. Before this the gale had been blowing at more than 30 miles an hour. The lowest point which the barometer reached was 29.05 according to the records at the City Engineer Office. At the Old Dartmouth Historical Society the barometer went slightly below 29 according to the Assistant Curator. During the gale of 1869 the barometer stood at 29.02. The total rainfall went well above the five and a half inch mark being officially recorded at 5.52 inches. This is the heaviest rainfall on record here. The only storm at which yesterday's storm can be compared is the 1869 gale, according to the City Engineer.

"As the rain decreased in volume this afternoon, the wind gained in velocity ripping up trees by the roots and tearing away whatever was in its path and not firmly anchored; blew over one house.

"New Bedford waterfront suffered comparatively little damage in the storm due to the fact that the wind at its height blew down the river rather than on shore."

A-4. HURRICANE TRACKS

The tracks of four notable hurricanes causing tidal flooding and serious damages in the survey area, namely those of September 1815, September 1938, September 1944, and August 1954 are shown on Plate A-1. The paths of Hurricane "Diane," (1955) a storm which brought record rainfall to many areas in southern New England, and Hurricane Donna (1960), the most recent storm to cross the New England coast, are also shown on the plate.

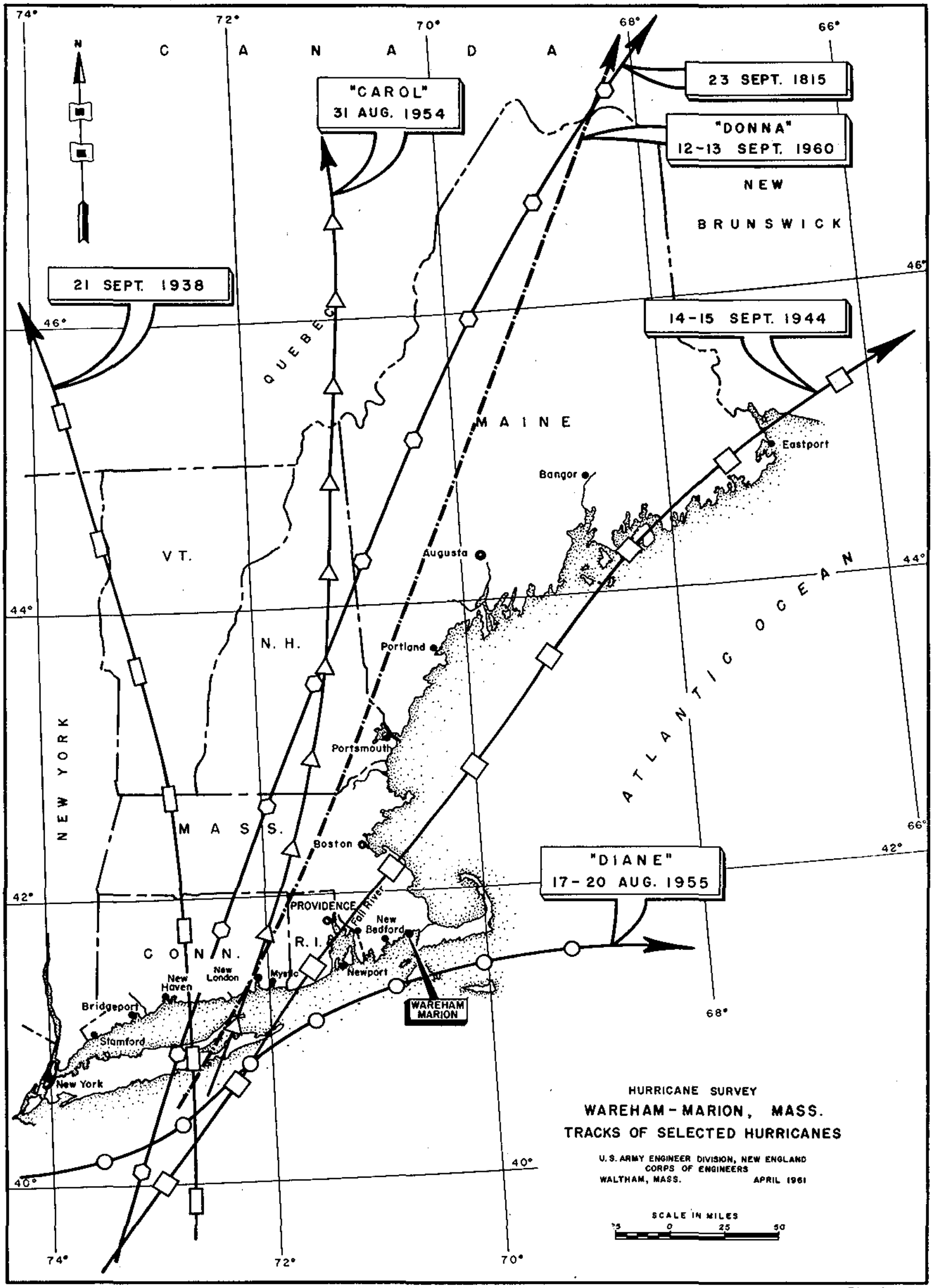
CANADA
"CAROL"
31 AUG. 1954
23 SEPT. 1815
"DONNA"
12-13 SEPT. 1960
NEW
BRUNSWICK
21 SEPT. 1938
14-15 SEPT. 1944
QUEBEC
MAINE
Eastport
Bangor
VT.
Augusta
ATLANTIC OCEAN
Portland
N. H.
NEW YORK
Portsmouth
MASS.
Boston
"DIANE"
17-20 AUG. 1955
PROVIDENCE
Fall River
New Bedford
R. I.
CONN.
New Haven
New London
Mystic
Newport
WAREHAM
MARION
Bridgeport
Stamford
New York
HURRICANE SURVEY
WAREHAM-MARION, MASS.
TRACKS OF SELECTED HURRICANES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
APRIL 1961
SCALE IN MILES
25 0 25 50
74°
72°
70°
68°
66°
46°
44°
42°
40°

PLATE A-1

APPENDIX B

HYDROLOGY AND HYDRAULICS

APPENDIX B

HYDROLOGY AND HYDRAULICS

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PLATES

APPENDIX B

HYDROLOGY AND HYDRAULICS

INTRODUCTION

B-1. This appendix presents data to supplement the sections of the main report relating to the subjects of hydrology and hydraulics. It includes a summary of temperature and precipitation data to amplify the section of the report on "Climatology," and data on hurricane wind velocities, rainfall values, and barometric pressures to augment report material on the characteristics of hurricanes. Determinations of tidal flood levels and design storm tide, analyses of wave height, runup, overtopping, and current velocities and computations of ponding and modified flood levels are also included in this appendix.

HYDROLOGY

B-2. TEMPERATURE

Mean, maximum, and minimum monthly temperature data at the U.S. Weather Bureau Station at East Wareham, Massachusetts, for 34 years of record covering the period 1926 through 1960, are summarized in Table B-1 on the following page.

B-3. PRECIPITATION

Mean, maximum, and minimum monthly precipitation data at the U.S. Weather Bureau Station at East Wareham, Massachusetts, for 35 years of record dating back to 1926, are summarized in Table B-2.

TABLE B-1

MONTHLY TEMPERATURES (1926-1960)

East Wareham, Massachusetts

	Degrees Fahrenheit				Degrees Fahrenheit		
Month	Mean	Maximum	Minimum	Month	Mean	Maximum	Minimum
Jan.	12.9	37.4	18.9 (1)	July	70.7 (2)	80.4	61.1
Feb.	29.0	37.6	18.9	Aug.	69.4 (2)	79.1	59.7
Mar.	36.2	43.8	26.4	Sept.	62.8	72.7	52.8
Apr.	45.6	53.3	35.0	Oct.	52.8	63.3	42.6
May	55.5	63.6	44.4	Nov.	43.2	52.9	33.4
June	64.6	74.2	54.9	Dec.	31.8	41.3	22.3
				Annual	49.3		

(1) Extreme minimum, -24°F on 11 Jan. 1942
(2) Extreme maximum, 100°F on 28 Aug. 1948 and 11 Aug. 1949

TABLE B-2

MONTHLY PRECIPITATION (1926-1960)

East Wareham, Massachusetts

	Inches				Inches		
Month	Mean	Maximum	Minimum	Month	Mean	Maximum	Minimum
Jan.	4.14	8.29	0.90	July	2.87	5.87	0.00 (1)
Feb.	3.55	5.88	1.04	Aug.	4.29	12.61 (2)	0.74
Mar.	4.51	9.64	1.57	Sept.	3.72	12.15	0.86
Apr.	4.14	7.65	1.04	Oct.	3.44	7.04	0.84
May	3.35	9.18	0.47	Nov.	4.45	10.61	0.78
June	3.24	9.65	0.00 (1)	Dec.	4.28	9.06	1.33
				Annual	46.13	62.68 (3)	33.44 (4)

(1) June 1949 and July 1947
(2) Aug. 1946
(3) 1953
(4) 1930

B-4. DRAINAGE AREAS

The drainage area of the Weweantic and Wareham Rivers, above the proposed barrier crossings near their mouths, are 88 and 47 square miles, respectively. The drainage area contributing runoff to Onset Bay, above the proposed barrier crossing at the south end of Onset Island, is approximately six square miles. Owing to the extent of ponds, swamps, and bogs in this drainage area, only one-half of the area, or three square miles, is considered to be effective in contributing runoff to the area behind the Onset Bay barrier in a hurricane. Behind the proposed supplemental dike protection for the main business center of Wareham, the drainage area is about 58 acres.

B-5. HURRICANE RAINFALL

Among the greatest rainfalls associated with hurricanes in New England are those recorded for Connie and Diane in August 1955. Hurricane Connie, 11-15 August, caused rainfall varying from about four to six inches over southern New England and ended a period of drought. A week later, Hurricane Diane, 17-20 August, brought rainfall of 16 to 20 inches over Massachusetts. Although Wareham did not receive excessive rainfall in either of these storms, Hurricane Diane did cause a record fall of 13.1 inches in 55 hours (4.1 inches in 6 hours) at West Mansfield, 31 miles northwest of Wareham.

Values of rainfall at a number of New England locations, which may be considered indicative of amounts that can occur in the Wareham-Marion area, are shown on Table B-3 on the following page. The total rainfalls associated with recent hurricanes that have caused tidal flooding in the Wareham-Marion area are: 2.6 inches in September 1938, 3.1 inches in September 1944, and 1.4 inches in August 1954 (Hurricane Carol).

According to the U.S. Weather Bureau (Hydrometeorological Bulletin No. 33) the maximum possible rainfalls for 6-hour and 12-hour periods are 25.0 and 27.6 inches, respectively, for a 10-square-mile area, 22.1 and 25.0 inches, respectively, for a 30-square-mile area.

TABLE B-3

HURRICANE RAINFALLS

Southern New England Locations

Location	6-hr.	12-hr.	24-hr.	Storm Total	
	Accumulated Rainfall in Inches				
17-20 August 1955 - Hurricane Diane					
New Bedford, Mass.	2.2	2.6	2.7	3.9	(35 hr)
Westfield, Mass.	7.9	10.9	18.2	19.8	(48 hr)
Mendon, Mass.	6.4	6.7	9.9	13.8	(56 hr)
Milton, Mass. (Blue Hill Observatory)	5.5	8.3	9.9	13.8	(57 hr)
Mansfield, Mass.	4.1	5.8	8.5	13.2	(55 hr)
East Wareham, Mass.	-	-	-	5.0	
11-15 August 1955 - Hurricane Connie					
New Bedford, Mass.	2.4	4.0	4.2	4.3	(43 hr)
Norfolk, Conn.	2.3	3.0	5.4	8.7	(78 hr)
East Wareham, Mass.	-	-	-	3.1	-
11 September 1954 - Hurricane Edna					
New Bedford, Mass.	2.8	3.3	-	3.4	(15 hr)
Woonsocket, R.I.	4.8	5.8	-	6.3	(15 hr)
East Wareham, Mass.	-	-	-	4.9	-
30-31 August 1954 - Hurricane Carol					
New Bedford, Mass.	1.3	1.9	-	1.9	(13 hr)
Mendon, Mass.	4.3	4.9	-	5.1	(15 hr)
East Wareham, Mass.	-	-	-	1.4	
14-15 August 1953 - Hurricane Barbara					
New Bedford, Mass.	3.5	4.0	4.1	4.2	(26 hr)
East Wareham, Mass.	-	-	4.7	4.7	-
Plymouth, Mass.	-	-	4.7	4.7	-

TABLE B-3 (Cont'd)

HURRICANE RAINFALLS

Southern New England Locations

Location	Accumulated Rainfall in Inches 6-hr.	12-hr.	24-hr.	Storm Total
	12-15 September 1944			
New Bedford, Mass.	1.8	1.9	2.1	3.4 (53 hr)
New Haven, Conn.	3.9	4.0	4.0	8.5 (57 hr)
Newington, Conn.	5.3	5.3	5.4	7.7 (54 hr)
East Wareham, Mass.	-	-	-	3.1 -
	17-21 September 1938			
New Bedford, Mass.	0.5	0.9	1.1	2.2 -
Barre, Mass.	-	-	-	17.0 -
Springfield, Mass.	3.2	4.4	6.3	10.4 (95 hr)
East Wareham, Mass.	-	-	-	2.6

B-6. RUNOFF

There are no streamflow records for the Wareham and Weweantic Rivers. The nearest drainage area comparable to those of the Wareham and Weweantic Rivers, with gaging stations, is that of the Wading River. The Wading River gaging stations are located at West Mansfield and Norton, Massachusetts. The following tabulation shows a comparison of data pertinent to the Wading, Wareham, and Weweantic Rivers. An examination of these data indicate that the rates of runoff from the Wareham and Weweantic Rivers are equivalent to or less than that of the Wading River.

Description	Wading R. at Norton, Mass.	Wareham R. at mouth	Weweantic R. at mouth
Drainage area (sq. mi.)	42.4	46.8	88.4
Length of stream (miles)	14.2	10.9	14.2
Average stream gradient (for 11 miles)	.00164	.00108	.00142
Maximum length of area (miles)	13.6	10.9	17.4
Maximum width of area (miles)	5.1	5.4	9.1
Area of lakes and ponds (sq. mi.)	0.8	2.5	3.2

The topography in the above three areas is low and flat, with numerous lakes, swamps, and cranberry bogs which are conducive to low runoff and a relatively long period of concentration.

The total storm rainfall of 13.05 inches experienced at Mansfield, Massachusetts, as a result of the Hurricane Diane in August 1955, resulted in a flow of 1172 cfs (27.6 cfs per square mile) in the Wading River at Norton, whereas in a number of New England river basins flows of over 500 cfs per square mile were caused by nearly similar rainfalls during this same storm. Hurricane Diane caused no tidal-flood surge in Wareham and Marion.

The runoffs in the Wading River at Norton from rainfall antecedent and coincident with recent hurricanes which caused tidal-flooding at Wareham and Marion, are listed below, also the runoff of a 10-year frequency.

Hurricane	Runoff (c.f.s.)	Runoff (c.f.s/sq.mi.)
Sept. 1938	180	4.25
Sept. 1944	137	3.23
Aug. 1954 (Carol)	27	0.64
Sept. 1960 (Donna)	26	0.61
10-year runoff	690	16.30

The effect of runoff on modified flood levels behind the barriers are discussed in paragraph B-15c.

The runoff into Onset Bay, which has a relatively small drainage area, under conditions of a design hurricane has been predicated on a 10-year, 4-hour rainfall of 2.7 inches and the assumption that 50 percent of this rainfall, over an effective three square miles of the drainage area, would constitute runoff to the bay. See paragraph B-4.

In determining the residual ponding behind the supplemental dike protection for the main business center of Wareham, a 10-year, 6-hour rainfall of 3.1 inches, with an assumed 70 percent runoff, has been used coincident with the peak of a design hurricane.

B-7. HURRICANE WINDS

The most reliable data on experienced hurricane wind velocities in New England begin with the September 1938 hurricane. The maximum velocity in New England during this storm was a recorded gust of 186 mph at the Blue Hill Observatory in Milton, Massachusetts, 36 miles northwest of Wareham, where a sustained 5-minute wind of 121 mph was also recorded. At other locations in southern New England, sustained 5-minute velocities ranging from 38 to 87 mph were experienced.

During the hurricane of 14 September 1944, a maximum gust of 109 mph was registered at Hartford, Connecticut, about 100 miles west of Wareham. Sustained 5-minute velocities ranging from 33 to 82 mph were recorded at a number of locations along the southern New England coast during this same hurricane.

In southern New England, during Hurricane Carol, 31 August 1954, a gust of 125 mph was experienced at Blue Hill in Milton, Massachusetts, and a gust of 135 mph at Block Island, Rhode Island, 60 miles southwest of Wareham. Sustained 1-minute velocities ranging from 38 to 98 mph were registered at a number of localities.

Recorded wind velocities at a number of locations in southern New England, for the three great hurricanes of 1938, 1944, and 1954, are given in Table B-4.

B-8. HURRICANE BAROMETRIC PRESSURES

The center, or "eye" of the 1938 hurricane entered Connecticut about 15 miles east of New Haven (105 miles west of Wareham) at about 3:30 P.M.,EST, on 21 September, and then proceeded northerly at a rate of from 50 to 60 mph. The lowest pressure registered during the passage of this storm was 28.04 inches at Hartford, Connecticut.

In the hurricane of 14 September 1944, the "eye" of the storm passed inland between Charlestown and Point Judith on the south coast of Rhode Island, about 45 miles southwest of Wareham, at about 10:20 P.M., EST. It then continued in a northeasterly direction, veering out to sea at Boston, Massachusetts. The minimum recorded barometric pressure in southern New England during this storm was 28.31 inches at Point Judith. A low of 28.42 inches was experienced at New Bedford.

The center of Hurricane Carol, 31 August 1954, crossed the south shore of Connecticut in the vicinity of New London (75 miles west of Wareham) at about 10:30 A.M., EST, and then followed a general northerly path across New England. The minimum barometric pressures in New England upon the occasion of this hurricane were 28.20 inches at Storrs, Connecticut, 75 miles west of Wareham, and 28.26 inches at New London, Connecticut, 75 miles southwest of Wareham.

The minimum pressures recorded at a number of New England locations during these three great hurricanes of the past 22 years are given in Table B-5.

TABLE B-4

WIND VELOCITIES

NEW ENGLAND HURRICANES OF 1938, 1944, and 1954

Location	Velocity in Miles per Hour: Sustained 5-Min.	Sustained 1-Min.	Maximum Gust	Direction
		Hurricane of 21 September 1938		
New Bedford, Mass.	60	-	-	-
Milton, Mass. (Blue Hill Observatory)	121	-	186	S
Providence, R.I.	87	95	125*	SW
Block Island, R.I.	82	-	91	SE
Boston, Mass.	73	-	87	S
Nantucket, Mass.	52	-	57	SE
Hartford, Conn.	46	-	59	NE
New Haven, Conn.	38	-	46	NE
		Hurricane of 14 September 1944		
New Bedford, Mass.	-	-	85	-
Chatham, Mass.	-	85	100*	-
Fall River, Mass.	-	-	90	-
Block Island, R.I.	82	88	100	SE
Nantucket, Mass.	57	-	79	SW
Westerly, R.I.	-	-	75	-
New London, Conn.	-	-	70	-
Hartford, Conn.	50	62	109**	N
Providence, R.I.	43	49	90	SE
New Haven, Conn.	33	38	65	N to NE
Pt. Judith, R.I.	85*	90*	-	SSE
Milton, Mass.	67	77	-	-
		Hurricane of 31 August 1954		
New Bedford, Mass.	-	-	85	-
Block Island, R.I.	-	98	135	SE
Milton, Mass.	-	93	125	SE
Providence, R.I.	-	90	105	ESE
Boston, Mass.	-	86	100	SE
Nantucket, Mass.	-	72	77	SE
Hartford, Conn.	-	56	64	NE
New Haven, Conn.	-	38	65	N
Bridgeport, Conn.	-	-	60	-

* Estimated
** Taken from indicator; clocked for 4 seconds

TABLE B-5

MINIMUM BAROMETRIC PRESSURES

New England Hurricanes of 1938, 1944, and 1954

Location	Time (EST)	Barometer (Inches)
	Hurricane of 21 September 1938	
Boston, Mass.	5:30 P.M.	29.09
Milton, Mass. (Blue Hill Observatory)	-	29.01
Nantucket, Mass.	3:30 P.M.	29.39
Providence, R.I.	3:45	28.90
Block Island, R.I.	3:05 P.M.	28.66
Hartford, Conn.	4:17 P.M.	28.04
New Haven, Conn.	3:30 P.M.	28.11
	Hurricane of 14 September 1944	
Milton, Mass. (Blue Hill Observatory)	12.11 A.M. (15 Sept)	28.62
New Bedford, Mass.	11:45 P.M.	28.42
Fall River, Mass.	10:30 P.M.	28.53
Nantucket, Mass.	11:28 P.M.	29.04
Worcester, Mass.	10:50 P.M.	28.92
Providence, R.I.	11:15 P.M.	28.51
Point Judith, R.I.	10:20 P.M.	28.31
Block Island, R.I.	10:09 P.M.	28.34
Hartford, Conn.	9:50 P.M.	28.94
	Hurricane of 31 August 1954	
Boston, Mass.	12:00 Noon	28.83
Milton, Mass. (Blue Hill Observatory)	-	29.90
Falmouth, Mass.	11:00 A.M.	29.17
New Bedford, Mass.	-	29.05
Providence, R.I.	11:12 A.M.	28.79
Block Island, R.I.	10:00 A.M.	28.50
Storrs, Conn.	11:00 A.M.	28.20
New London, Conn.	10:00 A.M.	28.26
New Haven, Conn.	9:10 A.M.	28.77

B-9. HURRICANE OR STORM-TIDE FLOOD LEVELS

The heights of tidal flooding experienced during Hurricane Carol (1954) at a number of locations in Wareham and Marion and other shore areas along the southern New England coast were obtained during the course of damage survey work in the field. The elevations of these flood levels, referred to mean sea level, were then determined by a field level party. This information was supplemented by high water levels collected by this office after the September 1938 hurricane. Based on this information, profiles have been prepared of the 1938 and 1954 tidal-flood elevations between Willets Point, New York, at the western end of Long Island Sound, and the entrance to the Cape Cod Canal, at the eastern end of Buzzards Bay. A map and profile for the coast line, between the Rhode Island-Massachusetts State Line and the entrance to the Cape Cod Canal, are included with this report. See Plates B-1 and B-2. For the Wareham area, in the approximate vicinity of miles 180 and 183 on the profile, general levels of 14.2 feet msl in 1938 and 13.6 feet msl in 1954 are indicated. Tide curves for the 1938, 1944, and 1954 hurricanes are shown on Plate B-3.

In the preparation of tidal elevation-frequency data for the Wareham-Marion area, consideration was given to similar data which has been prepared for Newport Harbor, Rhode Island, which lies about 35 miles southwest of Wareham. The mean tide range at Newport Harbor is 3.5 feet; at the mouth of Wareham River, 4.1 feet. The tidal elevation-frequency curve for the Wareham River area is based on (1) observed tidal-flood elevations for the 1938, 1944, 1954 (Carol), and 1960 (Donna) hurricanes, and (2) Newport Harbor tidal elevation-frequency data stage related to the Wareham River area. Tidal elevation-frequency data for the Wareham River area is shown in Table B-6. The Wareham River frequency curve, see Plate B-4, represents a composite curve based on a 326-year period, 1635-1960, a 146-year period, 1815-1960, that influence the upper portion of the curve, and a 30-year period, 1931-1960, for which there is a continuous tide gage record, that determines the lower portion of the curve.

TABLE B-6

TIDAL ELEVATIONS VS FREQUENCY DATA

HURRICANES AND SEVERE STORMS

Wareham River Area, Massachusetts

Hurricane or Storm	Maximum Tidal Elevation(2) (ft.msl)	Frequency Plotting Position(1) Percent Chance of Occurrence in any one Year (1635-1960)	(1815-1960)	(1931-1960)
Hurricane, 3 Aug. 1638	16.4+	0.15		
Hurricane, 15 Aug. 1635	15.6+	0.46		
Hurricane, 21 Sept.1938	14.2 (3)		0.34	1.7
Hurricane, 31 Aug. 1954	13.6 (3)		1.03	5.0
Hurricane, 23 Sept.1815	13.2+		1.71	
Hurricane, 14 Sept.1944	9.5 (3)			8.3
Storm, 30 Nov. 1944	8.9			11.7
Hurricane, 12 Sept.1960	8.8 (3)			15.0
Storm, 7 Nov. 1953	8.1			18.3
Storm, 3 Mar. 1947	7.8			21.7
Storm, 19 Feb. 1960	7.6			25.0
Storm, 3 Mar. 1942	7.3			28.3
Storm, 12 Nov. 1947	7.3			31.7
Storm, 14 Feb. 1960	7.3			35.0
Storm, 7 Feb. 1951	6.9			38.3
Storm, 3 Apr. 1958	6.9			41.7
Storm, 29 Dec. 1959	6.9			45.0
Storm, 27 Jan. 1933	6.4			48.3
Storm, 3 Nov. 1951	6.4			51.7
Storm, 15 Feb. 1953	5.9			55.0
Storm, 10 Nov. 1958	5.9			58.3
Storm, 2 Dec. 1942	5.4			61.7
Storm, 31 Oct. 1947	5.4			65.0
Storm, 22 Oct. 1949	5.4			68.3
Storm, 23 Oct. 1953	5.4			71.7
Storm, 16 Oct. 1955	5.4			75.0
Storm, 1 Oct. 1936	5.1			78.3
Storm, 25 Nov. 1953	5.1			81.7
Storm, 13 Apr. 1953	5.1			85.0
Storm, 20 Mar. 1958	5.1			88.3
Storm, 3 Jan. 1960	5.1			91.7
Storm, 12 Dec. 1944	4.8			95.0
Storm, 8 Dec. 1950	4.8			98.3
Storm, 2 Nov. 1955	4.8			100.0

Footnotes on following page

TABLE B-6 (Cont'd

Notes:

(1) Calculated plotting position: $P = \frac{100\,(M-0.5)}{Y}$ where

P = Percent chance of occurrence in any one year
M = Number of the event
Y = Number of years of record

(2) Based on tidal elevation data for Newport Harbor, Rhode Island; stage related to Wareham River area, except as noted.

(3) Based on high water marks at Wareham, Mass.

B-10. DESIGN STORM-TIDE DERIVATION

The September 1944 hurricane transposed to a hypothetical path due north over water from Cape Hatteras, North Carolina, with an assumed forward speed of 40 knots and with center passing 49 nautical miles west of the western entrance to Buzzards Bay produces winds and surge most critical to the Wareham-Marion area. The U.S. Weather Bureau has provided wind fields for use of the Beach Erosion Board, the Texas A.& M. Research Foundation, and the U.S. Army Engineer Division, New England, for the determination of tide elevation at the mouth of Narragansett Bay for the transposed September 1944 hurricane. This furnishes the basis for determination of the corresponding tide elevation at the Wareham-Marion area at the eastern end of Buzzards Bay.

The relationship between the computed surge in Narragansett Bay at Newport, Rhode Island, in a transposed 1944 hurricane, as determined by Texas A. & M. Reasearch Foundation, and the observed 1938 hurricane surge at Newport was utilized, together with data on the observed surges at Wareham and Marion, in estimating a transposed 1944 hurricane surge at Wareham and Marion. This surge, approximating a Standard Project Hurricane surge, equals approximately 1.33 times the observed surge, derived as follows:

	Newport Harbor	Wareham & Marion
Observed 1938 hurricane tidal-flood level (feet msl)	10.8	14.2
Coincident predicted normal tide (feet msl)	2.4	3.1
Observed surge (feet)	8.4	11.1
Adopted design surge(1) (feet)	11.2	
Ratio, adopted design surge over observed surge (11.2/8.4)	1.33	
Design Hurricane Surge (feet) (11.1 feet x 1.33)		14.8

(1) January 1960 Design Memorandum No. 4, Hurricane Tidal Hydraulics, Fox Point Hurricane Barrier, Providence River, Providence, R.I.

A surge of 14.8 feet, which approximates a Standard Project Hurricane surge, has been adopted as the design surge at Wareham and Marion. The addition of this surge to a mean spring high water elevation of 3.1 feet msl gives a design tidal-flood elevation (stillwater level) of 17.9 feet msl.

B-11. DESIGN WAVE HEIGHTS

Design wave heights at the barriers and dikes in the Wareham-Marion hurricane protection plan have been determined for conditions of a wind velocity of 69.5 knots (80 miles per hour), from the south, for a duration of one-half hour, coincident with the occurrence of the peak of the design stillwater level. Significant wave heights of 7.0 feet, with a period of 5.8 seconds, have been derived for barriers at the mouths of the Weweantic and Wareham Rivers based on a fetch of 10 nautical miles between Gunning Point in Falmouth and Nobska Point on Cromeset Neck in Wareham. For the barrier at the entrance to Onset Bay, the significant wave height, based on a fetch of one nautical mile, has been determined to be 3.5 feet.

The Business Center Dike is well protected from serious wave attack during the design hurricane by surrounding high ground, the proposed Wareham Barrier, and the restricted fetch length. It has been estimated that the waves at this dike would not exceed one foot in height with a period of approximately two seconds. The Power Line Dike, partially sheltered by scattered ridges and a roadway, would be exposed to about two-foot waves. The design wave at the Great Neck Dike, governed by depth limitations, would be about 5.0 feet high with a period of 5.8 seconds.

The significant wave height, the average of the highest one-third of the waves in a wave train, was used in determining the stone sizes for slope protection, the top elevations of the various structures in the plan, and the amount of overtopping. The wave heights at the toe of the protective works have been calculated on the premise that the maximum wave height that can be sustained is equal to 0.78 times the depth of water at the toe. The wind velocities in the Wareham-Marion area of Buzzards Bay, during a design hurricane, were obtained from the isovel charts presented in the U.S. Weather Bureau's Memorandum HUR 7-68, dated 7 January 1960, and entitled, "Transposed September 1944 Hurricane SPH Isovel Charts for Buzzards Bay, Forward Speed 40 Knots." The wave periods were determined from the relationship $H_s/T^2 = 0.22$, where H_s is the significant wave height and T is the period.

B-12. WAVE RUNUP AND OVERTOPPING

Consideration of the amount of overtopping to be anticipated from breaking waves is important in the design of a protection plan since the overtopping contributes to the flooding or ponding that is experienced behind the protective dikes and barriers.

Overtopping was computed by using one-half hour time intervals throughout the overtopping period in the design hurricane.

Wave runup values were calculated using the material contained in Paper 925 of the Journal of the Waterways Division of the American Society of Civil Engineers, Volume 82, WW2, April 1956, by Thorndike Saville, Jr., entitled, "Wave Runup on Shore Structures." Overtopping computations were based on data in Beach Erosion Board Technical Memorandum No. 64, entitled, "Laboratory Data on Wave Runup and Overtopping on Shore Structures," with consideration being given to the wave spectrum.

Estimates of the overtopping to be anticipated in connection with the proposed protection plan for the Wareham-Marion area, in the event of a design hurricane with tidal flooding to an elevation of 17.9 feet msl, are summarized in Table B-7.

TABLE B-7

OVERTOPPING OF PROTECTIVE WORKS - DESIGN HURRICANE

HURRICANE PROTECTION PLAN

Wareham-Marion Area, Massachusetts

Protection	Top Elev.(1) (ft. msl)	Wave Runup (feet)	Top of Runup (ft.msl)	Duration (hours)	Overtopping Maximum 1/2-Hour Rate (cfs)	Overtopping Maximum 1/2-Hour Volume (ac.ft.)	Total Volume (ac.ft.)
Weweantic Barrier	21.0	7.9	25.8	2.5	1840	76	250
Wareham Barrier	21.0	7.9	25.8	2.5	5452	225	745
Onset Barrier	21.0	4.1	22.0	1.5	335	14	42
Power Line Dike	19.0	1.2	19.1	0.5		Negligible	-
Great Neck Dike	20.0	5.6	23.5	1.5	290	12	36
Business Center Dike	13.5	0.8	13.1	-	-	-	-

(1) Maximum

B-13. FLOW THROUGH NAVIGATION OPENINGS

Flow through the navigation openings have been computed using the formula:

$Q = C A \sqrt{2G H}$ in which
Q = Flow in c.f.s.
C = Coefficient of discharge
A = Waterway opening in square feet
G = Gravitational constant = 32.16
H = Net head in feet

The coefficient "C" was estimated at 0.75, based on data obtained from U.S.G.S. Circular No. 284, "Computation of Peak Discharge at Contractions". It is believed that this "C" value reasonably reflects the hydraulic losses which would occur through the opening. However, it is suggested, in the event that the project is authorized for construction, that flume tests be made for the openings in question to determine coefficients of discharge and velocity distributions. Model studies may well lead to design improvements, resulting in increased effectiveness of the openings and/or improved velocity patterns to the benefit of navigation.

B-14. VELOCITIES IN NAVIGATION OPENINGS

Plate B-5 shows plans and elevations of the ungated and partially gated navigation openings through the barriers, also tidal elevations and average current velocities in the openings during a mean tidal cycle. The maximum velocities in the openings through the Weweantic, Wareham, and Onset Bay Barriers, during a mean tidal cycle, with a range of 3.1 feet, would be 2.7, 3.0, and 2.2 knots respectively, and would occur on the flood of the tide. During a design hurricane, when a head differential of upwards of 10 feet would be experienced at the openings, average velocities in the openings would range up to 19 feet per second or about 11 knots.

B-15. MODIFIED FLOOD LEVELS

a. General. Flows through the navigation openings in the barriers, fresh water inflow from runoff, and the overtopping of barriers and dikes by breaking waves would combine to produce modified tidal-flood levels behind the protection in future hurricanes. An analysis was made of each of these three factors to determine their net and respective effects on future flood levels.

b. Effect of Navigation Openings. Inflow through the navigation openings constitutes the principal factor in modifying the elevations of tidal-flooding behind the barriers during a hurricane. The inflow and the reduction in tidal elevations attributable to the barriers and their navigation openings is dependent largely on the height and duration of the hurricane tide, in other words, on the shape of the tidal hydrograph in Buzzards Bay. The levels of tidal flooding behind the barriers, from flow through the openings, were determined from routings, using 30-minute time intervals and the flow equation given in paragraph B-13. The reductions in flood levels on the landward side of the barriers that can be attributed to the openings, for the 1938, 1954, and a design hurricane, are summarized below:

Storm	Flood Level (ft.msl)	Reductions in Flood Levels (feet) Weweantic Barrier	Wareham Barrier	Onset Barrier
1938 hurricane	14.2	4.1	4.0	4.5
1954 hurricane	13.6	3.0	3.2	3.2
Design hurricane	17.9	6.1	6.0	6.6

c. Effect of Frest Water Runoff. From the data tabulated in paragraph B-6, a runoff value of 4.0 cfs per square mile has been selected for use in computing the fresh water inflow to the areas behind the Weweantic and Wareham barriers for all hurricanes causing tidal flooding up to the record level of 14.2 feet msl experienced in 1938. Applying this runoff value to drainage areas of 88 and 42 square miles for a 4-hour ponding period, gives fresh water inflows from the Weweantic and Wareham Rivers in amounts of 120 and 60 acre-feet, respectively, which represent approximately 0.1 and 0.03-foot of storage on the water area behind the barriers. Area capacity curves for the Weweantic and Wareham Rivers, above the barrier locations, are shown on Plates B-6 and B-7.

For determining the inflow in the event of a design hurricane, a runoff value of 16.0 cfs per square mile - a runoff of 10-year frequency - has been selected. The inflow from this runoff would amount to 470 and 250 acre-feet, respectively, from the Weweantic and Wareham Rivers. These volumes would raise water levels behind the barriers by approximately 0.3 and 0.1 foot.

An estimated runoff of 1.35 inches, from a 10-year, 4-hour rainfall of 2.7 inches, see paragraph B-6, from an effective drainage area of three square miles, assumed concurrent with the occasion of a design hurricane, would contribute inflow of about 215 acre-feet to Onset Bay. This volume is equivalent to approximately

0.1 foot of storage over the bay area at a modified pool level in a design hurricane. The fresh water inflows into Onset Bay during other hurricanes equivalent to those that caused appreciable tidal flooding in the past, would be minor. An inflow of 50 acre-feet has been assumed for such conditions. An area-capacity curve for Onset Bay, above the barrier location, is shown on Plate B-6.

d. Effect of Wave Overtopping. As indicated in Table B-7, paragraph B-12, wave overtopping in a design hurricane would contribute 250 acre-feet of water to the area behind the Weweantic River Barrier, 745 acre-feet to the area behind the Wareham River Barrier, and 78 acre-feet to the area behind the Onset Bay Barrier. Under conditions of modified tidal-flood levels in a design hurricane, these volumes of overtopping would increase the water levels of the ponding areas behind the Weweantic and Wareham River Barriers by approximately 0.2 foot, behind the Wareham River Barrier by about 0.3 foot, and the level of the ponding behind the Onset Bay Barrier by about 0.05 foot. No overtopping would be experienced in the event of a recurring hurricane of 1938 magnitude causing tidal flooding to an elevation of 14.2 feet msl in Buzzards Bay.

e. Frequency of Modified Tidal-Flood Levels. Curves were prepared showing the frequency of occurrence of modified tidal-flood levels for the Weweantic and Wareham Rivers and Onset Bay with the protection plan in operation. The modified curve for the Wareham River is shown in Appendic C on Plate C-2. Routings of a number of hurricane hydrographs through the navigation openings, both experienced and synthetic, were employed in deriving the modified frequency curves for the Wareham River. The synthetic hydrographs were obtained by adding experienced hurricane surges (actual tidal-flood elevations minus predicted coincident normal tides) to a mean tidal cycle with the peak surge being positioned at various stages of the tide. For example, a synthetic 1938 hurricane on mean high water would be the hydrograph obtained by adding the 1938 surges to a mean tidal cycle with the peak surge occurring coincident with mean high water. A number of such hydrographs were prepared and routed through the openings in order to supplement the limited amount of data obtainable by using actual hurricane hydrographs. In preparing a modified frequency curve for the Wareham River, the following ten hydrographs were used:

Hurricane Hydrographs	Peak Elevations (ft. msl)
1938 experienced	14.2
1954 experienced	13.6
1938 on mean low water (synthetic)	9.3
1938 on mean sea level "	11.5
1938 on mean high water "	13.4
1944 on mean sea level "	10.6
1944 on mean high water "	13.0
1954 on mean low water "	9.5
1954 on mean sea level "	11.2
Design	17.9

Modified frequency curves for the Weweantic River and Onset Bay were prepared from routings of three hurricane hydrographs: a design hurricane, the 1938 experienced, and a synthetic 1938 on mean low water. These three were selected as representative of the larger number used for Wareham.

f. Summary. A summary of the modifications in tidal-flood levels above the three barriers in the protection plan for Wareham and Marion that would be effected by reason of (1) reduced flows through navigation openings, (2) inflow from interior runoff, and (3) overtopping from hurricane waves is contained in Table B-8. The effects of the contributions from the inflow of runoff and overtopping are added to the modified tide level obtained by routing tidal-flood flows through the openings. This is conservative and results in a slightly higher modified tide level than the one that would be obtained if the ponding of runoff and overtopping were reflected in the routings.

B-16. PONDING - MAIN BUSINESS CENTER DIKE

The volume of water that would pond behind the supplemental dike protection for the main business center of Wareham, in the event of a design hurricane, assuming 70 percent runoff from a 10-year, 6-hour rainfall of 3.1 inches from the drainage area of 58 acres, equals 10.5 acre-feet. This would cause ponding to an elevation of 7.7 feet msl or 1.1 feet above the stage where flood damage begins. Using a 100-year, 6-hour rainfall of 4.8 inches, the volume of runoff becomes 18.5 acre-feet which would cause ponding to an elevation of 8.9 feet msl. Only minor ponding would be experienced in the event of recurring 1938 and 1954 hurricane conditions. Area-capacity curves for the protected area behind the main business center dike are shown on Plate B-7.

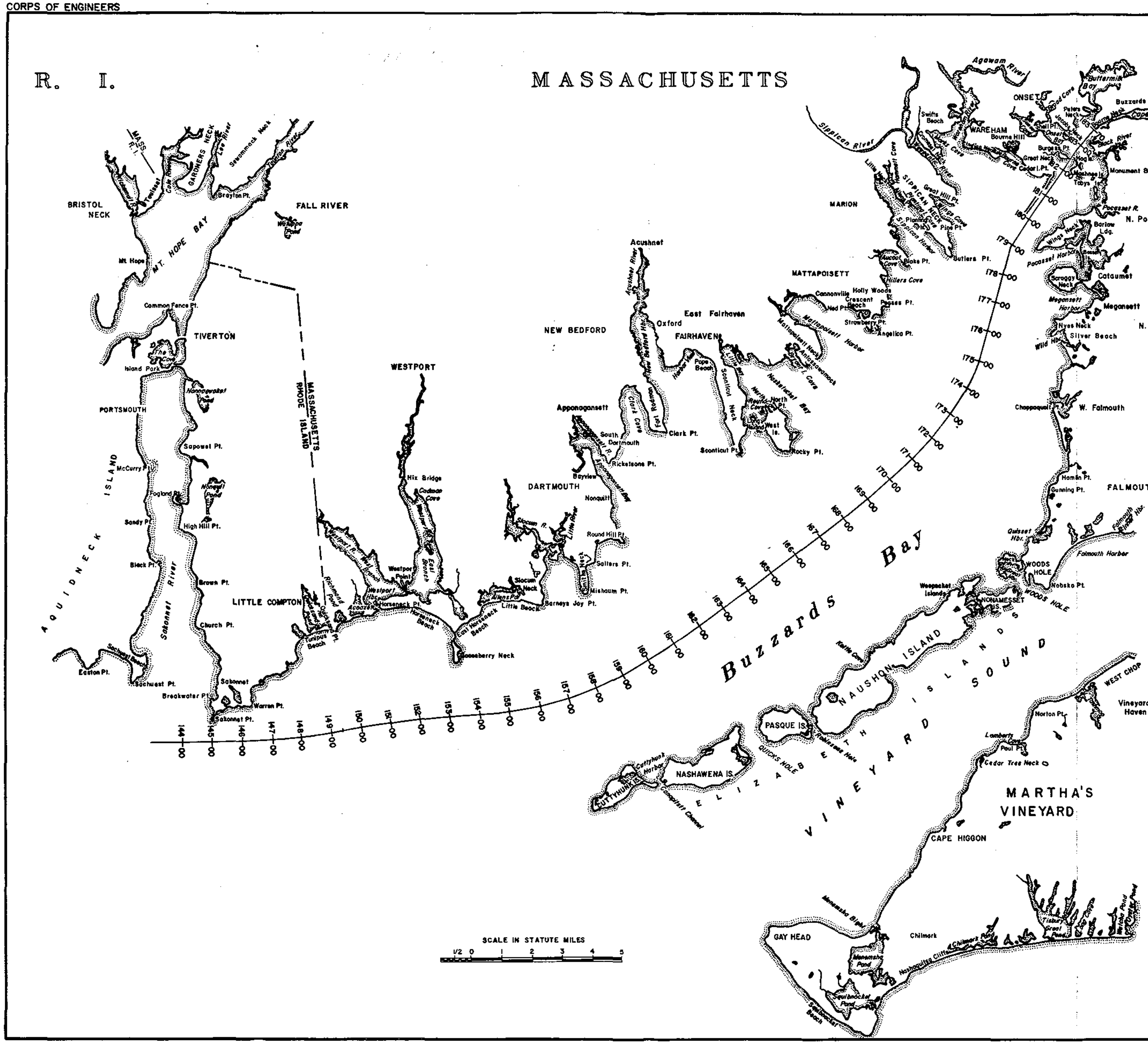
TABLE B-8

MODIFIED TIDAL-FLOOD LEVELS

HURRICANE PROTECTION PLAN

Wareham and Marion, Massachusetts

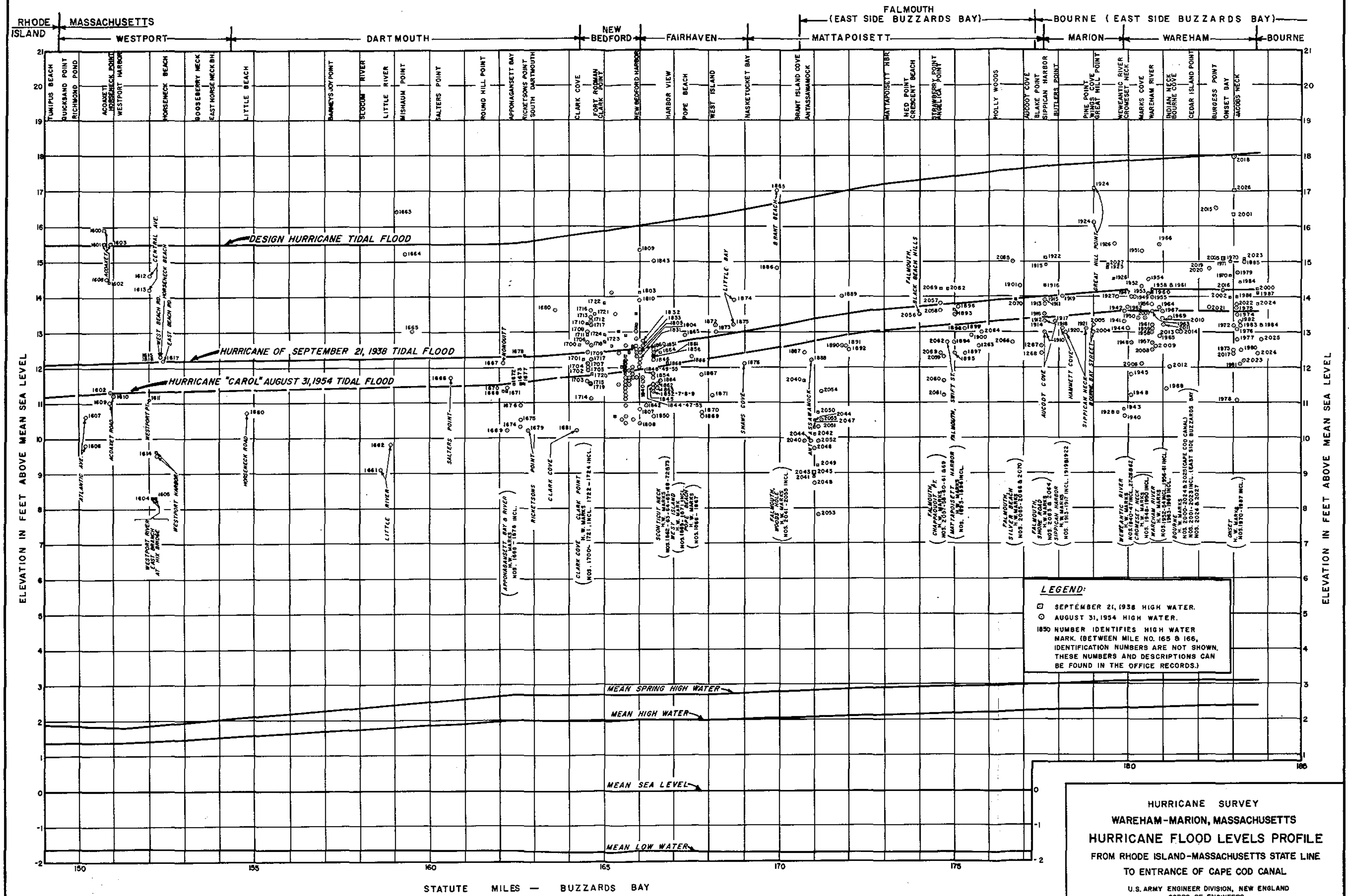
Recurring 1938 Hurricane	Weweantic Barrier	Wareham Barrier	Onset Barrier
Tide level, no protection (feet msl)	14.2	14.2	14.2
Reduction due to opening (feet)	4.1	4.0	4.5
Level modified by opening (feet msl)	10.1	10.2	9.7
Increase due to runoff (feet)	0.1	0.0	0.0
Increase due to overtopping (feet)	none	none	none
Modified flood level (feet msl)	10.2	10.2	9.7
Recurring 1954 Hurricane			
Tide level, no protection (feet msl)	13.6	13.6	13.6
Reductions due to opening (feet)	3.0	3.2	3.2
Level modified by opening (feet msl)	10.6	10.4	10.4
Increase due to runoff (feet)	0.1	0.0	0.0
Increase due to overtopping (feet)	none	none	none
Modified flood level (feet msl)	10.7	10.4	10.4
Design Hurricane			
Tide level, no protection (feet msl)	17.9	17.9	17.9
Reduction due to opening (feet)	6.1	6.0	6.6
Level modified by opening (feet msl)	11.8	11.9	11.3
Increase due to runoff (feet)	0.3	0.1	0.1
Increase due to overtopping (feet)	0.2	0.3	0.1
Modified flood level (feet msl)	12.3	12.3	11.5



HURRICANE SURVEY
WAREHAM-MARION, MASSACHUSETTS
LOCATION MAP FOR
HURRICANE FLOOD LEVELS PROFILE
FROM RHODE ISLAND-MASSACHUSETTS STATE LINE
TO ENTRANCE OF CAPE COD CANAL

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. APRIL 1961
SCALE AS SHOWN

CORPS OF ENGINEERS U. S. ARMY



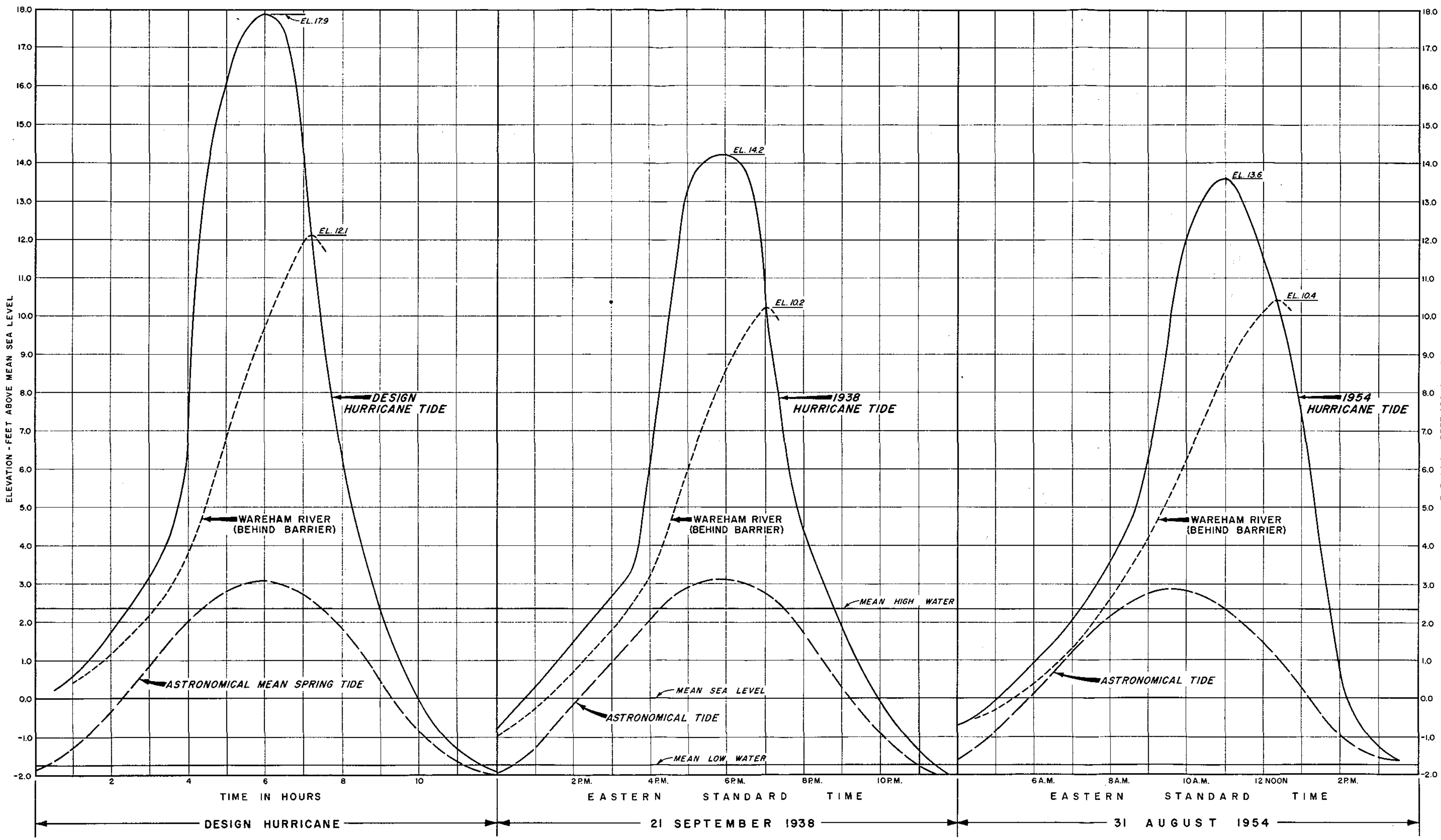
HURRICANE SURVEY

WAREHAM-MARION, MASSACHUSETTS

HURRICANE FLOOD LEVELS PROFILE

FROM RHODE ISLAND-MASSACHUSETTS STATE LINE TO ENTRANCE OF CAPE COD CANAL

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. APRIL 1961
SCALE AS SHOWN



NOTE:

Design hurricane tide curve based on Texas A&M surge calculations for a design storm with a track most critical to Buzzards Bay and with the peak of the surge coincident with the peak of an astronomical mean spring tide.

NOTE:

1938 - Hurricane tide curve based on high water marks at Wareham and hurricane tide at New Bedford, Mass.

NOTE:

1954 - Hurricane tide curve based on high water marks at Wareham and hurricane tide at Newport, R.I.

HURRICANE SURVEY

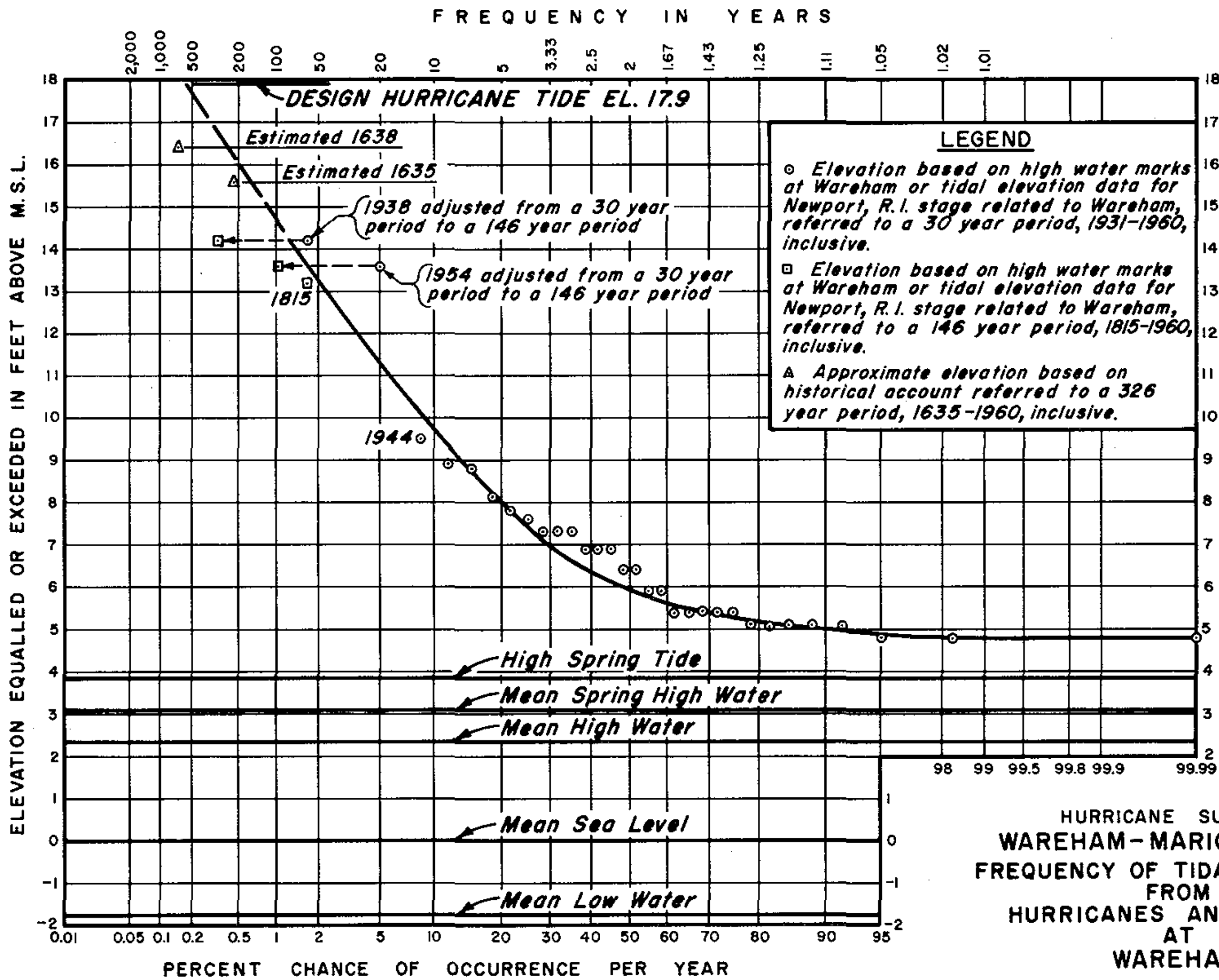
WAREHAM - MARION, MASS.

NATURAL & MODIFIED TIDE CURVES

DESIGN HURRICANE, - 1938 & 1954

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. MAR 1961

PLATE B-3



HURRICANE SURVEY

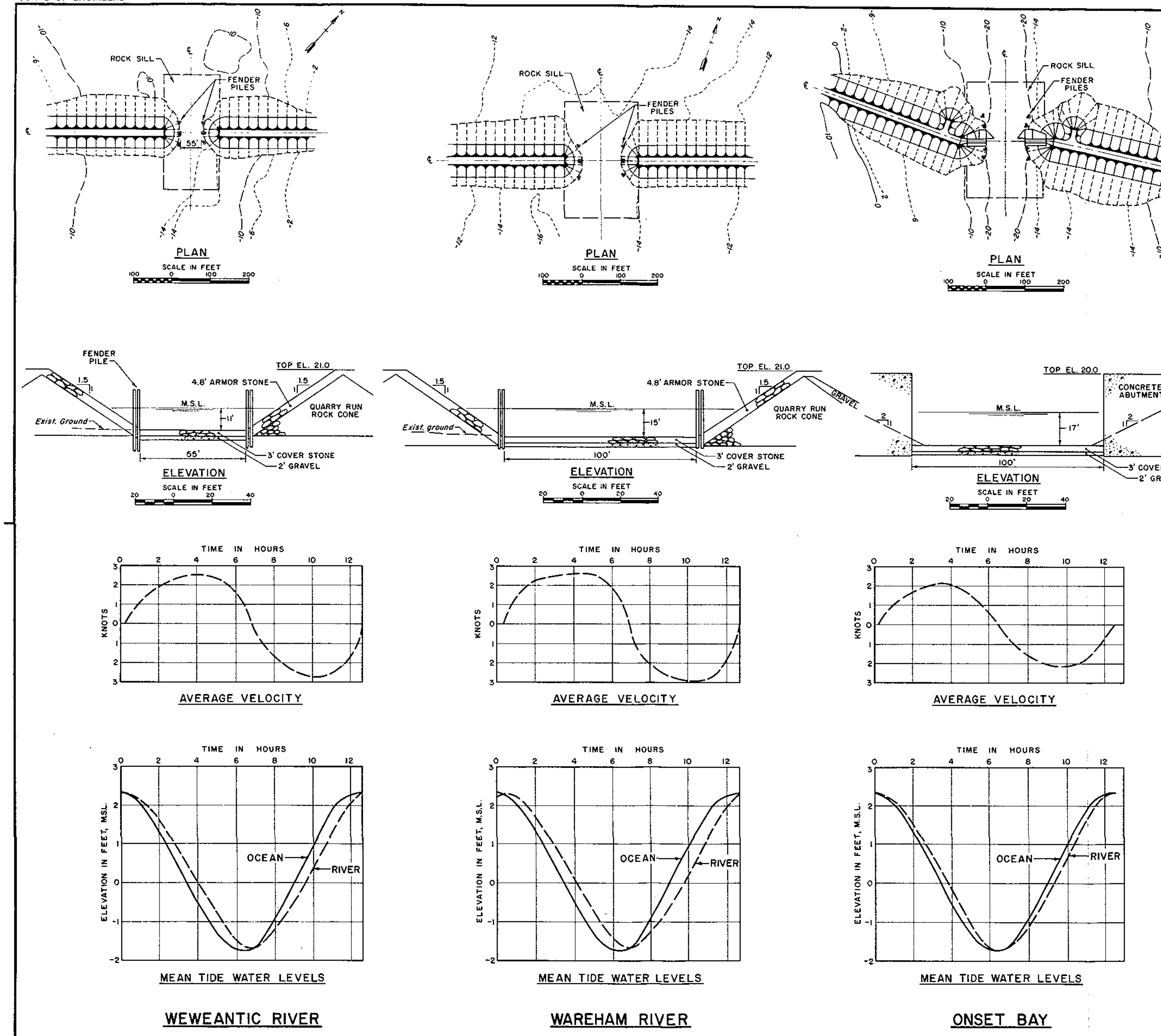
WAREHAM-MARION, MASS.

FREQUENCY OF TIDAL FLOODING FROM HURRICANES AND STORMS AT WAREHAM

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. 1961

CORPS OF ENGINEERS

U. S. ARMY



NOTES:

Elevations are in feet and are referred to mean sea level.
Average velocities are based on minimum area of navigation opening.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY
D.H.	R.J.C.	D.H.

SUBMITTED
CHIEF, HURRICANE UNIT NO. 2
PROJECT ENGINEER

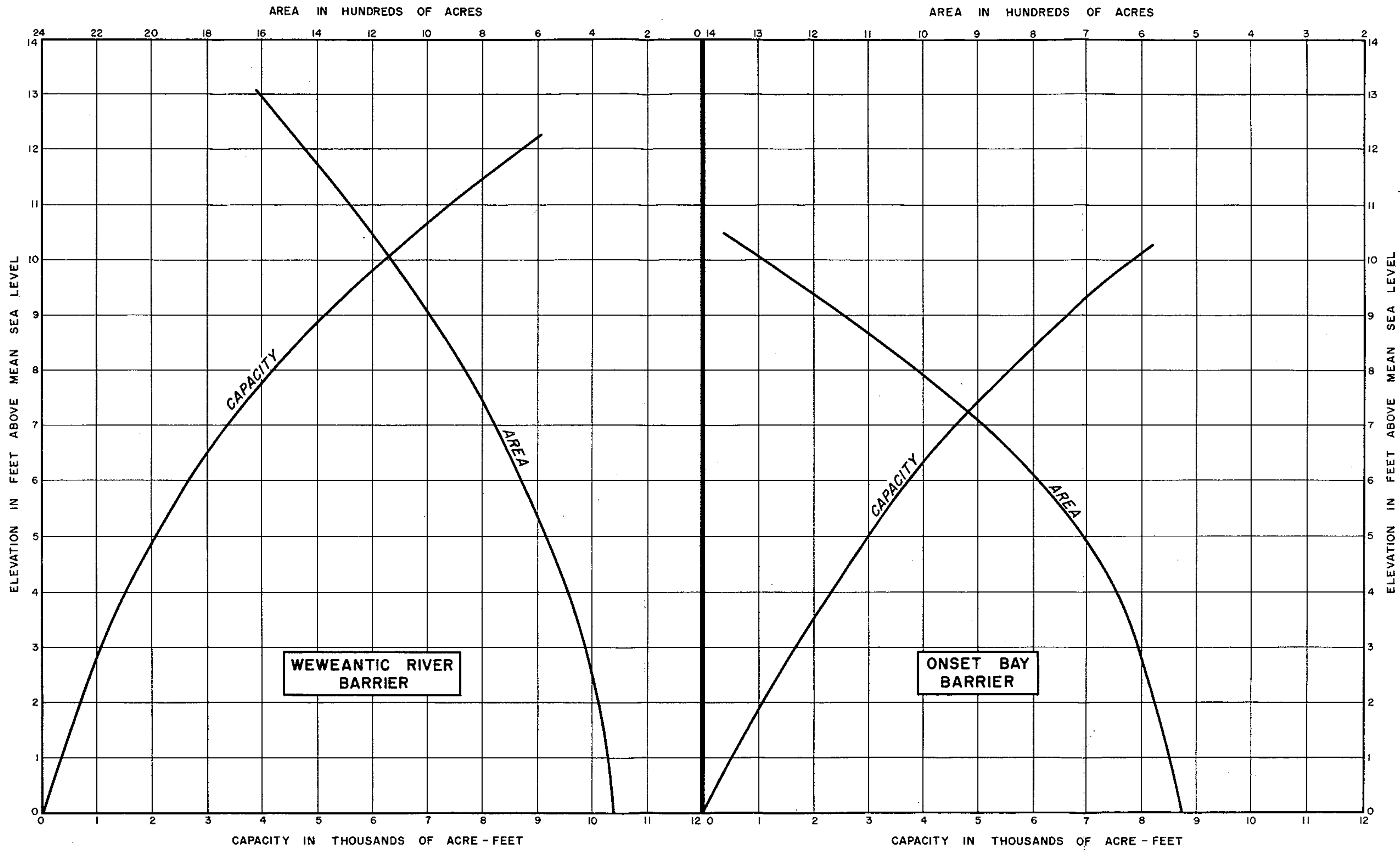
HURRICANE SURVEY
WAREHAM - MARION, MASS.
WEWEANTIC, WAREHAM & ONSET BAY
NAVIGATION OPENINGS
AVERAGE VELOCITY & MEAN TIDE LEVELS

APPROVAL RECOMMENDED
CHIEF, PLANNING & RPTS BRANCH
APPROVED
CHIEF, ENGINEERING DIV.
DATE OCT 1961

TO ACCOMPANY REPORT
DATED 25 OCT. 1961

SCALE AS SHOWN
DRAWING NUMBER
WMM - I - 1007
SHEET

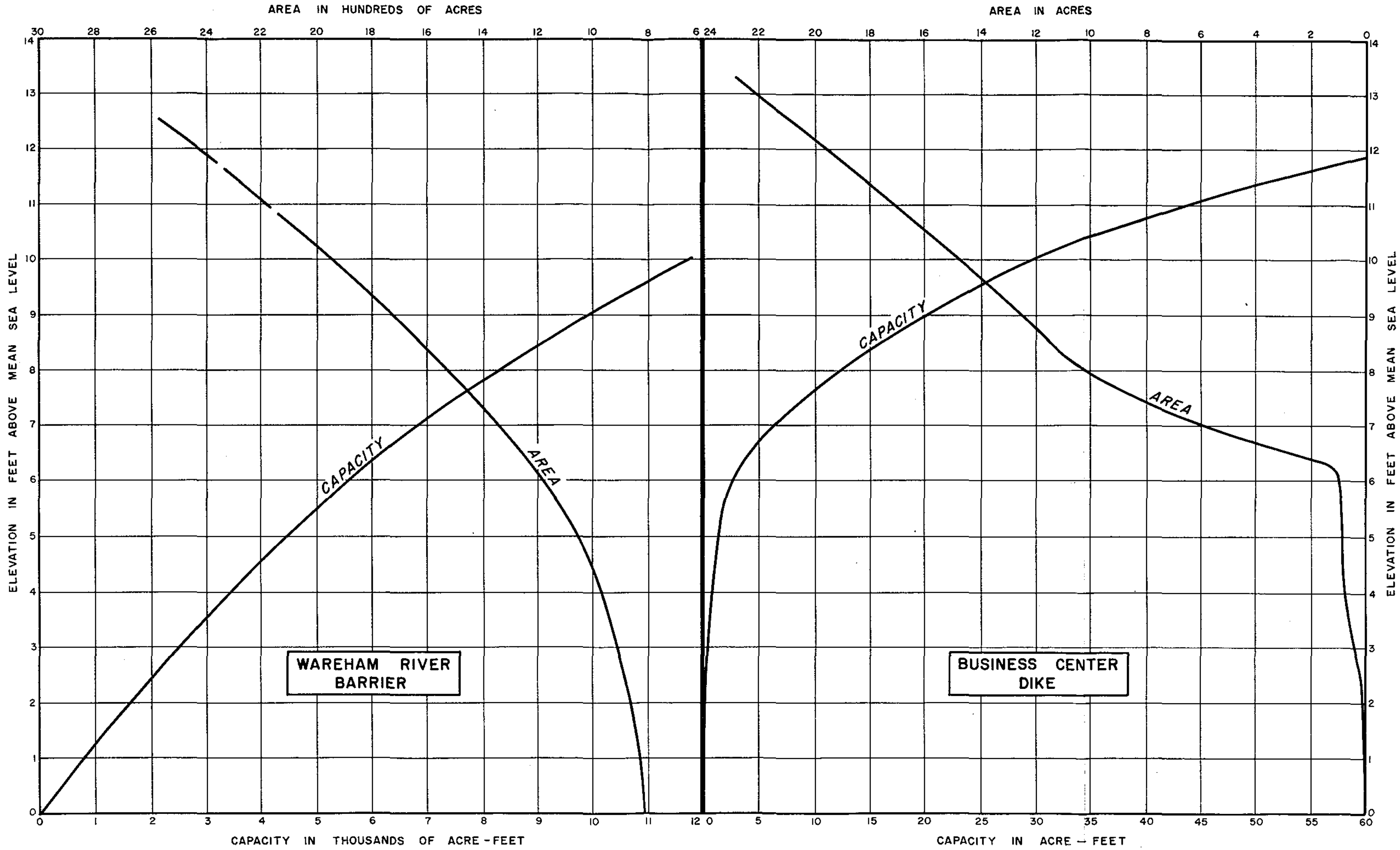
PLATE B-5



NOTE:
BASED ON U.S.G.S. MAPS.

HURRICANE SURVEY
WAREHAM - MARION, MASS.
WEWEANTIC RIVER
AND
ONSET BAY
AREA-CAPACITY CURVES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. MAR. 1961

PLATE B-6



NOTE

BASED ON U.S.G.S. MAPS.

HURRICANE SURVEY

WAREHAM - MARION, MASS.

WAREHAM RIVER
AND
BUSINESS CENTER
AREA-CAPACITY CURVES

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. MAR. 1961

PLATE 8-7

APPENDIX C

FLOOD LOSSES AND BENEFITS

APPENDIX C

FLOOD LOSSES AND BENEFITS

TABLE OF CONTENTS

APPENDIX C (Cont'd)

TABLES

PLATES

APPENDIX C

FLOOD LOSSES AND BENEFITS

GENERAL

C-1. DAMAGE SURVEYS

A preliminary damage survey was conducted in Wareham and Marion immediately after Hurricane Carol in 1954. A more detailed survey followed late in 1956 and additional surveys were made in 1959 and 1961 to check the extent of reconstruction of dwellings and cottages destroyed in the 1954 hurricane. The damage surveys were essentially door-to-door inspections of the residential, commercial, industrial, and other properties affected by tidal flooding. Local officials, real estate brokers, and other agencies provided a source of additional data. The information obtained included the extent and character of the flooded area, descriptions of the properties, including changed conditions since 1954, the nature and amount of damages, depths of flooding, high-water references, and relationships between the 1954 and other experienced tidal-flood stages. Information was also obtained to support conclusions on anticipated changes in land use prior to project construction. Evaluations of damage were generally furnished by tenants or property owners. Investigators used their own judgment in modifying these estimates, when appearing unreasonable, and also made their own estimates of damage in cases where owner or tenant was not available. Sampling methods were used where properties of the same general type, subject to the same depth of flooding, were encountered. Data on damages to public property, utilities, and highways were obtained from local officials and applied to field information. The survey area included the entire coastal shoreline of Wareham and Marion, Massachusetts, from the Wareham-Bourne town line on the east, at Buttermilk Bay, to the Marion-Mattapoisett town line on the west, at Aucoot Cove. This included the tidewater portions of the Wareham, Weweantic, and Agawam Rivers and Onset Bay.

Sufficient data were obtained to derive losses at the 1954 flood level, and at a stage 3 feet higher. The stage at which damage begins, referenced to the August 1954 flood stage, was also determined. Losses were also estimated for intermediate stages where marked increases in damage occurred.

Information on the valuation of the pleasure boat fleets based in the Weweantic and Wareham Rivers and Onset Bay and estimates of damage that could be sustained by the fleets in the event of future hurricanes were obtained from field interviews with local individuals familiar with the local pleasure boating activities. A field reconnaissance was made following Hurricane Donna in September 1960 to determine the extent of boat damages suffered at that time.

C-2. LOSS CLASSIFICATION

Flood loss information was recorded by type of loss and by location. The types of losses recorded included commercial, residential, public, industrial, highway, railroad, and utility.

The losses evaluated in the survey were tangible, primary damages. Primary damages comprise (1) physical losses, such as damage to structures, machinery, and stock, and cost of cleanup and repairs, and (2) non-physical losses, such as unrecovered loss of business, wages, or production, increased cost of operation, the cost of temporary facilities, and increased cost of shipment of goods into or out of the inundated areas.

The primary losses resulting from physical damages, and a large part of the non-physical losses, were determined by direct inspection of flooded properties and evaluation of the losses by property owners and field investigators. Where non-physical losses were difficult to estimate on the basis of available information, they were estimated by utilizing relationships between physical and non-physical losses for similar properties in the survey and other areas. No monetary evaluations were made of secondary damages or intangible losses. These losses include such items as loss of life, hazards to health, and detrimental effects on the national security.

HURRICANE TIDAL-FLOOD DAMAGES

C-3. TIDAL-FLOOD LOSSES TO SHORE PROPERTIES

The damages caused by tidal flooding to shore properties in Wareham and Marion during Hurricane Carol on 31 August 1954 amounted to $10,660,000. This damage was suffered by some 1,670 houses, of which 320 were completely destroyed, 120 commercial establishments, 4 public buildings, the buildings and grounds of one private school, and structures at two major industrial firms. Damage areas are described in Table C-1 and are shown on Plate C-1.

TABLE C-1

EXPERIENCED TIDAL FLOOD LOSSES - SHORE PROPERTIES

HURRICANE CAROL, 31 AUGUST 1954

Wareham and Marion, Mass.

		Losses in Thousands of Dollars					
Area	Description	Residential	Commercial	Industrial	Public	Highway & Railroad	Total
I	Mattapoisett town line (Aucoot Cove) to Butlers Point	1590	190	-	320	-	2,100
II	Butlers Point to Bass Point on west bank of Weweantic River	165	35	-	-	-	200
III	West bank of Weweantic and Sippican Rivers, above Bass Point	95	15	-	-	-	110
	Subtotals - Marion	1,850	240	--	320	--	2,410

Table C-1 continued on Page C-4

TABLE C-1 (Cont'd)

Area	Description	Losses in Thousands of Dollars					
		Residential	Commercial	Industrial	Public	Highway & Railroad	Total
IV	Drainage of Weweantic R. in Wareham, opposite and above Bass Point	*705	30	-	5	-	740
V	Drainage of Wareham River above Nobska and Long Beach Pts.	4,210	1,165	370	25	20	5,790
VI	Drainage of Onset Bay above line from Burgess to Sias Pt. along south side of Onset Island	970	330	-	50	30	1,380
VII	Shore from Long Beach to Burgess Pt., and lower end of Cromeset Neck	30	-	-	-	-	30
VIII	Shore from Sias Pt. east to Bourne town line	245	65	-	-	-	310
	Subtotals, Wareham	6,160	1,590	370	80	50	8,250
	Totals, Wareham and Marion	8,010	1,830	370	100	50	10,660

C-4. TYPES AND DISTRIBUTION OF EXPERIENCED LOSSES - SHORE PROPERTIES

Residential damages account for 75 percent of the total loss of $10,660,000 experienced by shore properties in Wareham and Marion during Hurricane Carol in 1954. Commercial losses, concentrated chiefly in the business center of Wareham, in Onset village, and in the village center of Marion, account for 17 percent of the total losses in 1954. A tabulation of 1954 experienced tidal-flood losses in Wareham and Marion, by damage area and by type of loss, is shown in Table C-1.

In Area I, from the Mattapoisett town line to Butlers Point, including Aucoot Cove and Sippican Harbor, losses caused by tidal flooding in 1954 amounted to $2,100,000. Some 205 residences, 46 commercial structures owned by 14 firms, including 5 major boat yards, 31 school buildings at Tabor Academy, and 45 two-story buildings at a summer church colony were flooded. Five structures of the Aucoot Boat Yard were completely destroyed forcing the company to rebuild on higher ground. Flooding on the west shore of Sippican Harbor was extensive with some structures experiencing as much as 4 feet of flooding above first floor levels. Similar stages were noted in the area around Hammet Cove, at the upper end of Sippican Harbor, and at Allens Point on the east shore. Losses on Planting Island and Sippican Neck were chiefly to grounds and cellars.

In Area II, the shoreline from Butlers Point to Bass Point, fronting on Buzzards Bay, 27 homes, 5 commercial firms, 2 golf and 2 beach clubs sustained losses amounting to $200,000. The clubhouse and 10 cabanas of the Piney Point Beach Club were swept into Buzzards Bay during the height of the storm. Many windows, at both cellar and first flood levels, were smashed by flood waters and floating debris.

In Area III, along the west banks of the Weweantic and Sippican Rivers, in Marion, from Bass Point to Bear Swamp, flooding caused damages totaling $110,000. Some 27 residences, 5 commercial establishments, a golf club and a beach club experienced flooding up to 4 feet deep over first floor levels. Damages to lawn and shrubbery was extensive throughout this reach.

In Area IV, the Wareham portion of the Weweantic River drainage area, opposite and above Bass Point and above the lower 1,500 feet at southeast end of Cromeset Point, tidal flooding caused damages of about $740,000. Approximately 190 cottages experienced flooding up to 5 feet over first floors in the beach areas at Rose Point, Weweantic Shores, and Briarwood Beach. Forty-one of the cottages were totally destroyed. Several acres of cranberry crops were flooded by salt water.

Area V, the drainage area of Wareham River above Nobska and Long Beach Points, experienced damages of $5,790,000, or nearly 55 percent of the total 1954 damage in Wareham and Marion. In the business center of Wareham some 30 commercial establishments, 6 homes, 4 public buildings, and 2 major industrial firms sustained damages totaling $1,370,000. Depths up to 7 feet over first floors were noted in this highly commercialized area. A total of 764 year-round residences, rental properties, and cottages, and 5 commercial establishments were flooded at Pinehurst Beach, Parkwood Beach, Hamilton Beach, Swifts Beach, and Cromeset Neck. Of these, 260 dwellings were totally destroyed. In addition, some 35 cottages, a commercial firm, and a cranberry bog were flooded in the village of Oakdale, on the east bank at and above the head of Wareham River.

In Area VI, the drainage area of Onset Bay, above a line from Burgess Point to Sias Point, along the south side of Onset Island, the damages caused by tidal flooding in 1954 amounted to $1,380,000. In the highly developed village center of Onset some 230 houses and 9 commercial firms experienced flooding up to 5 feet deep over first flood levels. Across the East River, in the Point Independence area, tidal flooding affected some 121 homes and summer cottages and 7 commercial firms, 2 yacht clubs, and a hotel. Heavy damages were also sustained by 83 homes at Agawam Beach at the upper end of Sunset Cove, on Onset Island, and at Jacobs Neck on the mainland directly north of Onset Island.

Damages in Area VII, which includes the shoreline from Long Beach Point to Burgess Point, and the lower end of Cromeset Point, amounted only to $30,000. Almost all of the loss was experienced by 11 summer dwellings on Cromeset Point. The remaining area in this reach is mainly undeveloped shoreline and marshes.

In Area VIII, the shoreline from Sias Point eastward to the town line at Bourne, some 30 year-round residences, 24 cottages, and 10 commercial firms experienced damages totaling $310,000. Nearly all of the commercial establishments are located along Route U.S. 6 on Long Neck, on the north shore of Butlers Cove. Flooding reached stages up to 5 feet above first floors in this area.

C-5. RECURRING LOSSES - SHORE PROPERTIES

Stage-damage curves, referenced to the 1954 tidal flood level, were prepared from data obtained from recent field investigations. These curves afford a means of determining the recurring losses at any stage of flooding up to a stage 3 feet higher than that experienced in 1954. The recurring losses reflect economic and physical changes in the study area since Hurricane Carol. In some instances they include anticipated new developments prior to project construction. The recurring losses from damage to shore properties in the flooded areas of Wareham and Marion, in the event of future hurricanes, and in the areas protected by the proposed three-barrier plan are shown in Table C-2.

TABLE C-2

RECURRING TIDAL-FLOOD LOSSES - SHORE PROPERTIES

Wareham and Marion, Massachusetts
(1961 Price Level)

Equivalent Hurricane	Flood Stage (ft.msl)	Entire Flooded Area	Protected Area	Damages Prevented
21 Sept. 1938	14.2	$13,800,000	$10,~~6~~7 00,000	9,640,000
31 Aug. 1954	13.6	10,610,000	7,970,000	6,720,000*
14 Sept. 1944	9.5	1,040,000	600,000	

ANNUAL LOSSES AND BENEFITS

C-6. GENERAL

The total benefits to the hurricane protection plan for Wareham and Marion comprise benefits obtainable from (1) the prevention of tidal-flood damage to shore properties, (2) the elimination of emergency costs, and (3) the prevention of storm damage to boats.

C-7. AVERAGE ANNUAL TIDAL-FLOOD LOSSES

a. Damages to shore properties. Recurring losses to shore properties at various hurricane tidal-flood stages in Wareham and Marion have been converted to average annual losses to provide a basis for determining the annual benefits to be used in economic evaluation of hurricane tidal-flood protection. The stage-damage data, obtained as part of the flood loss survey, was correlated with elevation-frequency information to derive damage-frequency relationships for each area where protection was considered. The damage-frequency curve has been plotted with damage as the ordinate and percent-chance-of-occurrence (the reciprocal of frequency) as the abscissa. The area under this damage-frequency curve, see Plate C-2, is a measure of the average annual loss. The total average annual loss in the two towns, predicated on all stages of flooding up to a design hurricane tidal-flood level of 17.9 feet msl, is estimated at $712,000. A breakdown of this total, by damage areas, is contained in Table C-4. Nearly 70 percent of this total annual loss is in the protected area behind the barriers and dikes in the selected plan.

b. Emergency costs. Temporary protective measures to minimize anticipated flood damages are undertaken by many home owners, commercial firms, industrial plants, boat owners, and others upon the receipt of a hurricane warning. These measures include steps such as the sandbagging or boarding up of windows and other openings, and the evacuation of space likely to be flooded by the removal of goods, machinery, motors, etc. to higher floor levels or entirely outside the flooded area. These are costs that are incurred even though flooding is not experienced. It is estimated that the emergency costs sustained within the two towns by reason of a single hurricane threat amount to $46,000 of which $30,000 is attributable to properties within the protected area of the three-barrier plan. Based on an assumed frequency of three warnings every 10 years, which is considered to be conservative, the emergency costs would average $9,000 a year for properties behind the protection.

c. Storm Damage to boats. The present pleasure boat fleets based in the Weweantic and Wareham Rivers and Onset Bay, numbering about 760 boats, together have an estimated total valuation of $6,000,000. See Table C-3. Pleasure boating in New England waters has increased considerably during the past 10 years and it is reasonable to assume that the trend will continue and that a substantial growth in the valuation of the local fleet will be realized within the next 100 years. It is estimated, based on anticipated population growth in the nearby suburban areas and the anticipated increase in personal income per capita that the total value of the local fleet will increase to $30,000,000 (at the 1961 price level), or to five times its present value, by the end of the next 100 years. This anticipated increase in the size and value of the local fleet approaches the limit that can be reasonably accommodated in the project area.

Storm damages of approximately $600,000, or 10 percent of the fleet valuation, were experienced by the fleet in Hurricane Donna, September 1960, and similar damage can be expected in a recurrence of this hurricane which has an occurrence frequency of about 14.5 percent. In a future hurricane equivalent to Carol in 1954, with an occurrence frequency of 1.7 percent, the present fleet would sustain estimated damages of $3,000,000 equivalent to 50 percent of fleet valuation. The damages in a design hurricane, causing flooding to 17.9 feet msl, would exceed $5,000,000. On an annual basis, the storm damage to the present pleasure boat fleets in the three Wareham waterways would be $370,000. With a 500 percent growth in fleet valuation by the end of a 100-year period, the average annual damage at the end of the period would be increased to $1,850,000.

TABLE C-3

ANNUAL LOSSES AND BENEFITS
(1961 Price Level)
STORM DAMAGE TO PLEASURE BOATS

Wareham and Marion, Massachusetts

Item	Weweantic R.	Wareham R.	Onset Bay	Total	Sippican Harbor
Sailboats:-					
Number & Avg.Length	-	50 @ 20 ft.	10 @ 22 ft.	60	150 @ 15 ft. 225 @ 32 ft.
Average Unit Value	-	$ 2,600	$ 3,000		$ 1,200 $ 10,000
Total Value	-	$ 130,000	$ 30,000	$160,000	$2,430,000
Outboards:-					
Number & Avg.Length	50 @ 16 ft.	150 @ 18 ft.	50 @ 16 ft.	250	100 @ 16 ft.
Average Unit Value	$ 1,000	$ 1,200	$ 1,200		$ 900
Total Value	$50,000	$ 180,000	$ 60,000	$290,000	$ 90,000
Inboard Cruisers:-					
Number & Avg. Length	25 @ 25 ft.	200 @ 20-32 ft. 100 @ 32-42 ft.	100 @ 25-40 ft. 25 @ 40-50 ft.	450	100 @ 26 ft.
Average Unit Value	$ 5,000	$ 5,000 $ 23,000	$ 15,000 $ 25,000		$ 8,000
Total Value	$125,000	$3,300,000	$2,125,000	$5,550,000	$ 800,000
Commercial:-	None	None	None	None	None
Total Fleet Valuation	$175,000	$3,610,000	$2,215,000	$6,000,000	$3,320,000

Note: Data on size and estimated valuation of local fleets obtained from interviews with local boat yard operators, yacht club stewards, and harbormasters.

C-8. AVERAGE ANNUAL BENEFITS

a. Prevention of damages to shore properties. Average annual benefits from the prevention of tidal-flood damages to shore properties were derived by determining the difference between the average annual losses under existing conditions and those remaining after construction of the project. In the main business district of Wareham, a supplementary dike is proposed which will eliminate practically all the residual annual losses remaining in this area after construction of the Wareham River Barrier. The average annual tidal-flood prevention benefits attributable to the entire plan, including the Business Center Dike, total $458,000. A breakdown of this total, by damage areas, is contained in Table C-4.

b. Elimination of emergency costs. The proposed protection will eliminate the need for incurring of emergency costs by property owners and tenants in the areas behind the structures in the protection plan. This benefit is estimated at $9,000 a year.

c. Prevention of damage to boats. The total annual storm damage to the pleasure boat fleets in the Weweantic and Wareham Rivers and Onset Bay, under present conditions, is estimated at $370,000 for the 1960 fleet and at $1,850,000 for the fleet expected at the end of 100-year growth period. Personnel acquainted with the problem of storm damage to boats have estimated that the three barriers in the Wareham-Marion protection plan, by reducing wave heights and lowering the levels of tidal flooding, would reduce the storm damage by amounts ranging from 50 percent with flooding to or above a 1954 level of 13.6 feet msl to 35 percent with flooding to a 1960 level of 8.7 feet msl, to zero reduction with flooding at an elevation of6.0 feet msl (2.15 feet above a high spring tide). The correlation of these reductions with stage-frequency data gives an average annual benefit of $130,000 from the prevention of damage to the present fleets. The remaining annual damages of $240,000 would be mainly attributable to wind and would not be affected by the protection works.

The average annual benefit at the end of a 100-year period has been similarly determined to equal $650,000, an increase of $520,000 over the benefits predicted on the present fleet. Using a growth period of 100 years, a project life of 100 years, and an interest rate of 2.625 percent gives an average annual equivalent factor of 0.30995 for a straight line growth in the value of the fleet. Applying this factor to the increase of $520,000 in average annual benefits gives an average annual equivalent of $160,000 which represents the average annual benefit from the prevention of storm damage to the future increases in the local pleasure boat fleet over the next 100 years. Adding this to the average annual benefit of $130,000 from prevention of damage to the present fleet gives a total average benefit of $290,000.

d. Summary of benefits. The total annual benefits attributable to the protection plan amount to $757,000 of which $458,000 is from the prevention of damage to shore properties, $9,000 from the elimination of emergency costs, and $290,000 from the prevention of damage to boats.

TABLE C-4

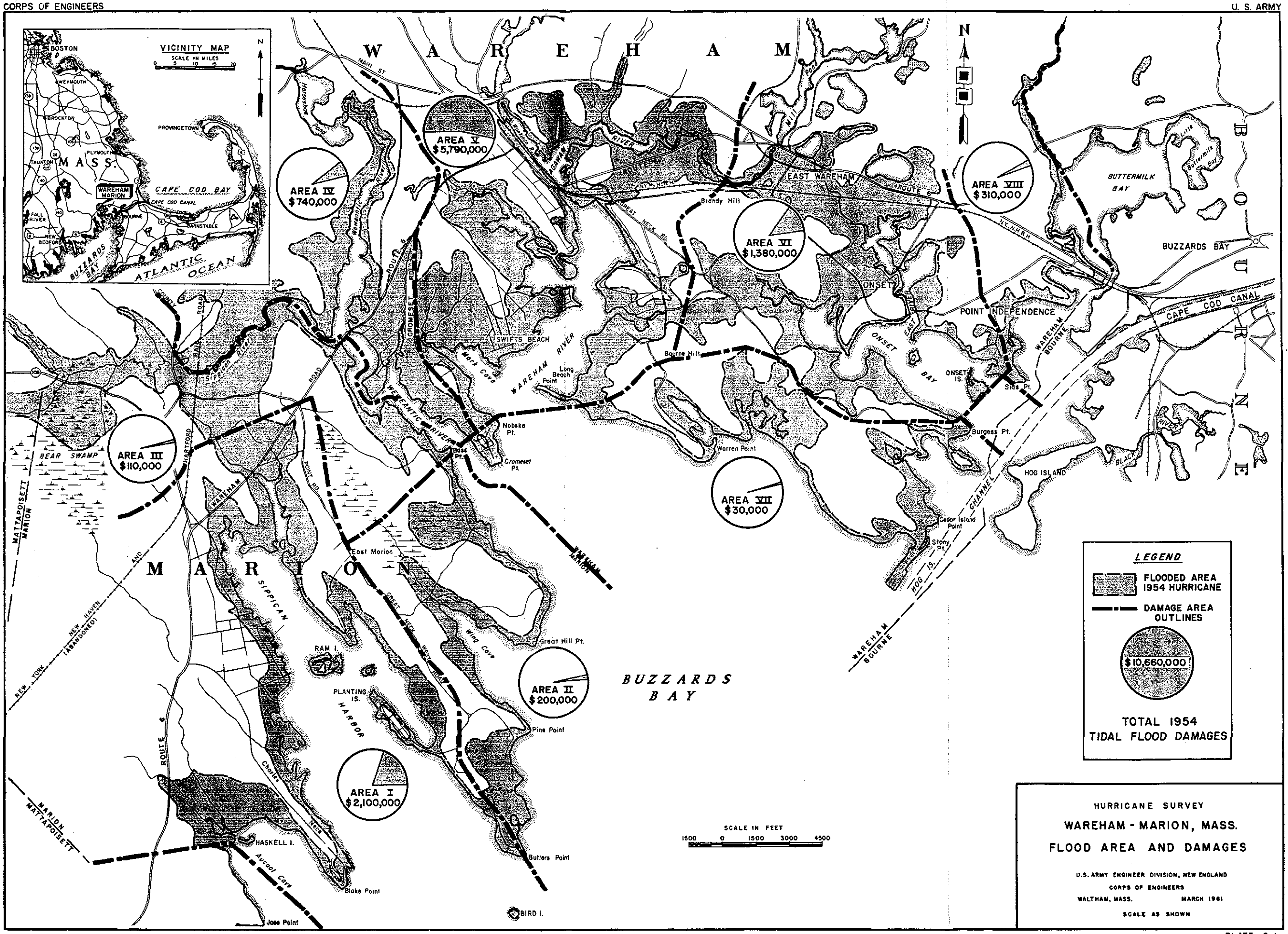
ANNUAL LOSSES AND BENEFITS
(1961 Price Level)

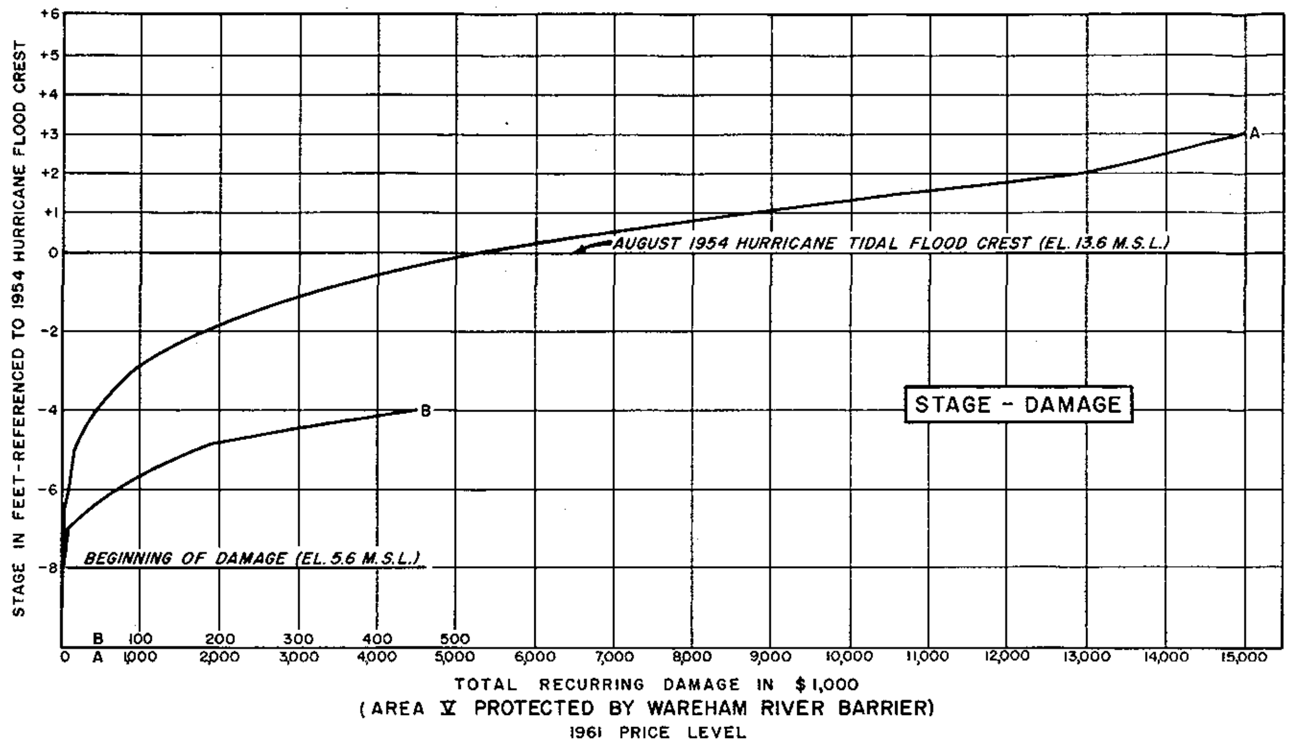
TIDAL-FLOOD DAMAGES TO SHORE PROPERTIES

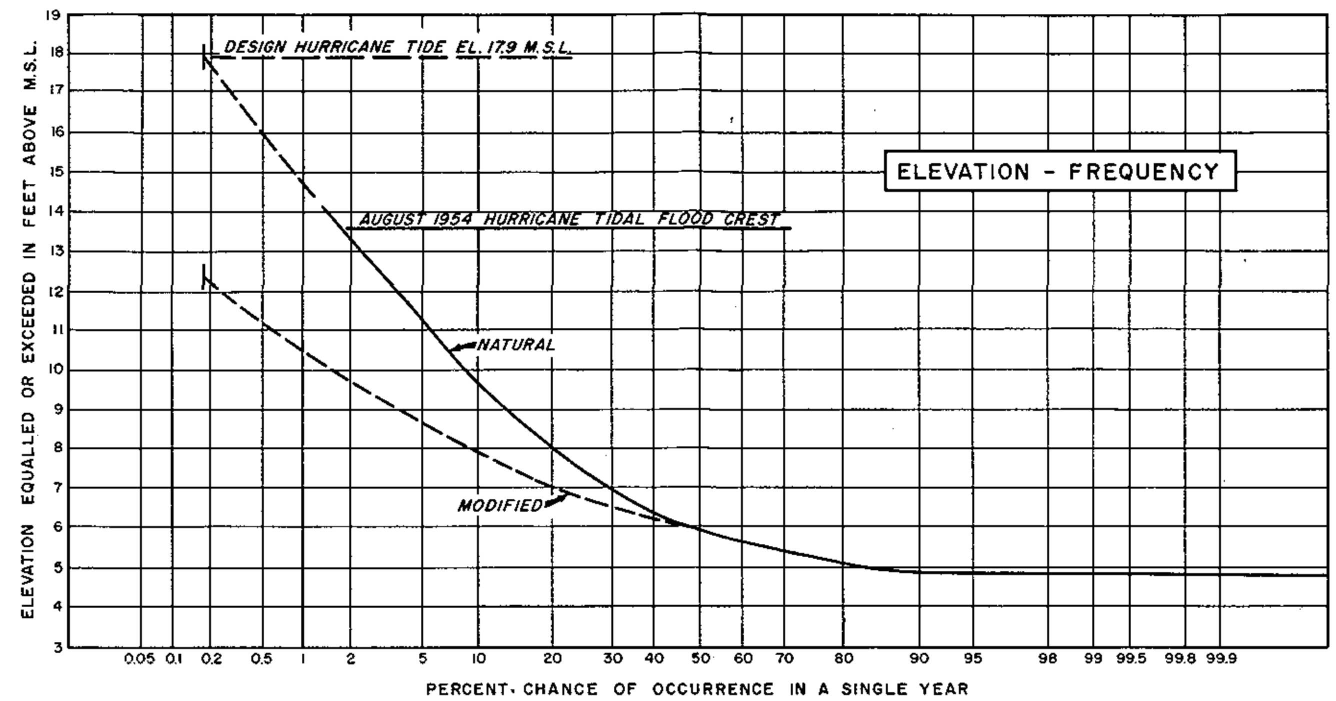
Wareham and Marion, Massachusetts

Area	Description(1)	Annual Losses: Without Protection	Annual Losses: With Protection	Benefit
I*	West of Butlers Pt.	$167,000	$167,000	-
II*	Butlers Pt. to Bass Point	35,000	35,000	-
III	West bank, above Bass Point	10,500	2,300	$8,200
	Subtotals, Marion	$212,500	$204,300	$8,200
IV	Weweantic River in Wareham	51,400	6,200	45,200
V	Wareham River	336,700	14,900	
	Barrier		(43,800)(2)	292,900
	Business Center Dike		(14,900)	28,900
VI	Onset Bay	89,700	6,900	82,800
VII*	West of Burgess Pt.	1,700	1,700	-
VIII*	East of Sias Pt.	20,000	20,000	-
	Subtotals, Wareham	$499,500	$ 49,700	$449,800
	Totals, Wareham and Marion	$712,000	$254,000	$458,000

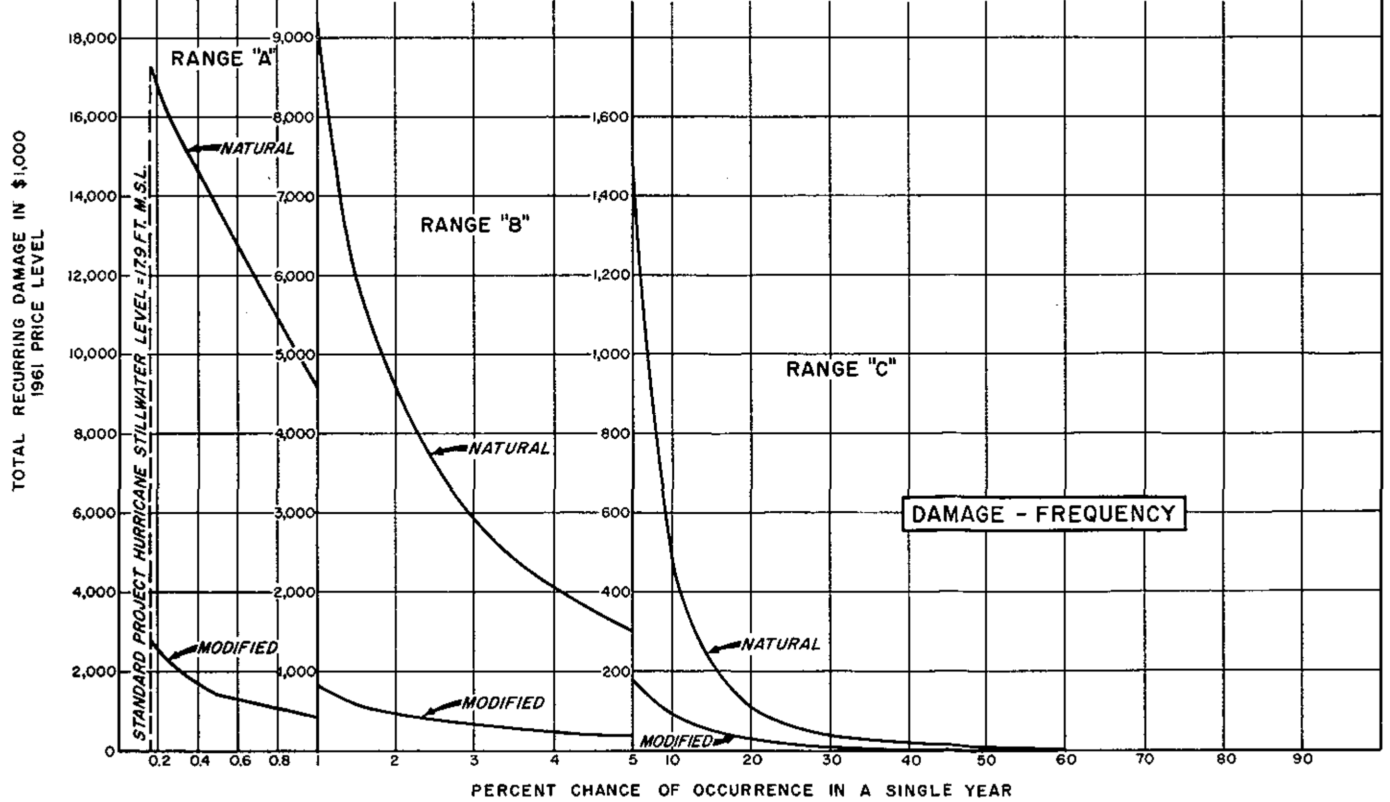
(1) See Table C-1 for more complete description
(2) After barrier protection alone, without business center dike
* Outside protection plan


VICINITY MAP
SCALE IN MILES
BOSTON
WEYMOUTH
BROCKTON
PLYMOUTH
TAUNTON
MASS.
PROVINCETOWN
CAPE COD BAY
WAREHAM MARION
CAPE COD CANAL
BOURNE
BARNSTABLE
FALL RIVER
NEW BEDFORD
BUZZARDS BAY
ATLANTIC OCEAN
W A R E H A M
M A R I O N
AREA I $2,100,000
AREA II $200,000
AREA III $110,000
AREA IV $740,000
AREA V $5,790,000
AREA VI $1,380,000
AREA VII $30,000
AREA VIII $310,000
BUZZARDS BAY
BUTTERMILK BAY
BUZZARDS BAY
CAPE COD CANAL
ONSET BAY
WAREHAM RIVER
WEWEANTIC RIVER
SIPPICAN HARBOR
SWIFTS BEACH
EAST WAREHAM
ONSET
POINT INDEPENDENCE
BEAR SWAMP
HASKELL I.
RAM I.
PLANTING IS.
BIRD I.
HOG ISLAND
Great Hill Pt.
Butlers Point
Blake Point
Pine Point
Bourne Hill
Brandy Hill
Warren Point
Burgess Pt.
Nobska Pt.
Cromeset Pt.
East Marion
LEGEND
FLOODED AREA 1954 HURRICANE
DAMAGE AREA OUTLINES
$10,660,000
TOTAL 1954 TIDAL FLOOD DAMAGES
SCALE IN FEET
1500 0 1500 3000 4500
HURRICANE SURVEY
WAREHAM - MARION, MASS.
FLOOD AREA AND DAMAGES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. MARCH 1961
SCALE AS SHOWN





	RANGE "A" 1□" = $8,000			RANGE "B" 1□" = $10,000			RANGE "C" 1□" = $20,000			TOTAL	
	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	ANNUAL LOSS	ANNUAL BENEFIT
NATURAL	13.60	$108,800	—	14.25	$142,500	—	4.27	$85,400	—	$336,700	—
MODIFIED	1.60	$12,800	$96,000	1.62	$16,200	$126,300	0.74	$14,800	$70,600	$43,800	$292,900



HURRICANE SURVEY

WAREHAM-MARION MASS.

CURVES FOR ECONOMIC ANALYSIS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. MAY 1961

APPENDIX D

DESIGN STUDIES AND COST ESTIMATES

APPENDIX D

DESIGN AND COST ESTIMATES

TABLE OF CONTENTS

APPENDIX D (Cont'd)

DESIGN AND COST ESTIMATES

APPENDIX D

DESIGN AND COST ESTIMATES

INTRODUCTION

D-1. This appendix presents design features and cost estimates for the selected plan of hurricane protection for the Wareham-Marion area, Massachusetts. The principal features of the plan are shown on Plates D-1 through D-5.

The design and cost estimates for the selected plan are based on topographic and hydrographic surveys and subsurface explorations accomplished in 1960. The extent of subsurface investigations is covered in paragraph D-5.

D-2. COASTAL GEOLOGY

The long shoreline of Wareham is a complexity of ice contact slopes, partially submerged kettle holes, and wave-built shoreline features. The water bodies in Wareham, all merging southward into Buzzards Bay, are, from west to east, the Weweantic River, the Wareham River, Onset Bay, and Buttermilk Bay. Exposure is to the south and southwest where wind fetch is limited to only a few miles because of a barrier effect produced by the Elizabeth Islands, an east-west morainic chain of islands protruding from the west side of Cape Cod. In the northeastern area of Buzzards Bay, a dredged channel, 32 feet deep, extends southwesterly into the bay from the west end of the land cut portion of the Cape Cod Canal. The embayed estuary of Buzzards Bay, below the mouths of the Wareham and Weweantic Rivers, is separated from the dredged channel by Stony Point Dike, an artificial bar, two miles long, constructed from sand and gravel spoil from the dredged channel. The embayment entrance extends west from the top of this artificial bar to Butlers Point, a distance of about two miles. The mouths of the Weweantic and Wareham Rivers lie about three miles north northwest of the embayment entrance. Despite the area's protection from heavy wave action, severe hurricane tidal flooding extends well inland, owing to the generally low and flat characteristics of the area. Marine features and groin-drift accumulations indicate predominant littoral drifting shoreward on each side of the Wareham embayment, converging in the vicinity of the mouth of the Wareham River. This indicates, therefore, a relatively stable situation for the placement of the artificial beach material proposed in this report. Additional assurance of stability is offered by the longevity (about two decades) of the Stony Point Dike which occupies a more vulnerable position. Protection from scour at the proposed navigation openings through the barriers, however, is necessary.

DESIGN CRITERIA

D-3. The structures have been designed to withstand a design hurricane producing a stillwater elevation of 17.9 feet msl, accompanied by significant waves 7.0 feet high at the mouths of the Weweantic and Wareham Rivers, 3.5 feet high at the mouth of Onset Bay, 2.0 feet high along the power line in Marion, north of Sippican Harbor, and 5.0 feet high along Great Neck Road in Wareham. In many locations the wave size becomes dependent on the ground elevation which, in turn, establishes the depth of water available to support a wave. Elevations varying from 19.0 to 21.0 feet msl were selected for the top of structures in order to provide protection against conditions of a design hurricane stillwater level and design waves. One exception to this is the supplemental protection for the main business center of Wareham where elevations of 13.0 and 13.5 feet msl have been set for the top of structures on the basis of a modified stillwater level of 12.3 feet msl in a design hurricane after construction of the Wareham River barrier downstream.

In the case of a design wave breaking against the protective structures at the time of peak flooding in a design hurricane, the overtopping would not appreciably reduce the effectiveness of the structures. A discussion of the design hurricane and wave overtopping is contained in Appendix B.

SELECTED PLAN OF PROTECTION

D-4. DESCRIPTION OF PLAN

a. General. The selected plan of protection consists of barriers, with openings for navigation, across the mouths of the Weweantic River, the Wareham River, and Onset Bay; five closure dikes connecting the ends of the barriers to adjacent high ground; two supplemental closure dikes, one in Marion, along the power line north of Route U.S. 6, and one in Wareham, along Great Neck Road about 1.5 miles west of Burgess Point; and supplemental dike protection along the west bank of the Wankinco and Wareham Rivers at the main business center of Wareham. Included in the plan of improvement are:

(1) Ungated navigation openings with bottom widths of 55 and 100 feet in the Weweantic and Wareham River barriers, respectively.

(2) A partially-gated navigation opening, 100 feet wide, in the Onset Bay Barrier.

(3) Three stoplog structures varying from 30 to 60 feet in width and 3 to 6 feet in height; one at the crossing of a railroad and two at highway crossings.

(4) Eight highway ramps, three providing dike crossings by public highways and private roadways and five providing access from private driveways to a roadway raised to the top of a dike. The alignments and location of all structures are shown on Plates D-1, D-2, D-3, and D-5.

b. Weweantic River Protection. The Weweantic River Barrier, about 1050 feet long, crossing the Weweantic River in the vicinity of Bass Point in Marion, would be of earth-fill, rock-faced construction, with a top elevation of 21.0 feet msl and a top width of 20 feet. A quarry-run rock toe, to facilitate placement of the earth fill, would be provided on the seaward side of the barrier. The barrier would be tied to high ground in Marion , on the west, by Bass Point Dike, about 900 feet long, and to high ground in Wareham, on the east, by Nobska Dike which would extend about 1,300 feet across Cromeset Neck to Nobska Point. The dikes would be of earth-fill, rock-faced construction and have a top width of 10 feet and a top elevation ranging from 20.0 to 21.0 feet msl. See Plate D-2.

The Power Line Dike in Marion, approximately 4,800 feet long, would be constructed of earth fill with rock on the top and seaward slope and gravel on the landward slope. It would have a top elevation of 19.0 feet msl and a top width of 10 feet. See Plate D-5.

The ungated navigation opening in the Weweantic River Barrier would have a bottom width of 55 feet, side slopes of 1.0 on 1.5 and a sill elevation of 11.0 feet below msl. The sill, extending about 150 feet on each side of the barrier, would consist of a three-foot layer of stone resting on a two-foot layer of gravel. See Plate D-9.

c. Wareham River Protection. The Wareham River Barrier, approximately 4,150 feet long, would extend across Wareham River from Nobska Point on Cromeset Neck to a point on the opposite shore about 500 feet south of the inner end of Long Beach Point. The barrier would be of earth-fill, rock-faced construction, with a top elevation of 21.0 feet msl and a top width of 20 feet, similar to the Weweantic River Barrier. The west end of the barrier would be tied directly into high ground at Nobska Point; the east end would be tied to high ground by Long Beach Dike extending inland approximately 1,300 feet. This dike would be of earth-fill, rock-faced construction, and have a top width of 10 feet at elevations of 20.0 and 21.0 feet msl.

The ungated navigation opening in the Wareham River Barrier would have a bottom width of 100 feet, side slopes of 1.0 on 1.5, and a sill elevation of 15.0 feet below msl. The sill would be of rock and similar to the sill in the opening through the Weweantic River Barrier. See Plate D-9.

d. Onset Bay Protection. The Onset Bay Barrier, approximately 2,800 feet long, would cross the entrance to Onset Bay, between Burgess Point on the southwest and Sias Point on the northeast, along an alignment that follows, in part, the southeast shore of Onset Island. The barrier would be of earth-fill, rock-faced construction, with a top elevation of 20.0 feet msl and a top width of 20 feet. The west end of the barrier would be tied to high ground at Burgess Point on Great Neck by Burgess Dike extending inland about 1,000 feet. This dike would be constructed of earth fill with rock facing, similar to the Bass Point, Nobska, and Long Beach Dikes, with a top elevation of 19.0 feet msl. Closure to high ground in Onset, at the eastern end of the barrier, would be accomplished by Sias Dike running inland for approximately 1,800 feet following, for the greater part of this distance, the present alignment of Robinwood Road. For approximately 1,500 feet of its length the dike would be of earth fill with rock facing and have a top width of 24 feet at elevations varying from 19.0 to 20.0 feet msl. A 16-foot wide paved roadway would be provided on top of the dike to replace present Robinwood Road. Ramps would be provided where necessary to afford access to the elevated Robinwood Road from private driveways. Closure would be completed at the north end of the protection by about 300 feet of rock-faced, earth-filled dike with a top width of 10 feet. Great Neck Dike, approximately 900 feet long, would also be constructed of earth fill with rock facing. It would have a top width of 10 feet and a top elevation of 20.0 feet msl. See Plate D-3.

The navigation opening in the Onset Bay Barrier would have a bottom width of 100 feet, vertical side walls, and a sill elevation of 17.0 feet below msl which is equivalent to the present project channel depth. The opening is provided with two 20 x 20-foot gates which would be closed during a hurricane in order to reduce the area of the opening and thereby increase its effectiveness in lowering tidal-flood levels behind the barrier. The gates would be mounted on concrete abutments and, when in an open position, would rest on a gate pad on each abutment. The gates would be opened and closed by means of a pin rack and sprocket connected through reduction gears to an electric motor. Power for operation of both gates would be secured from a 20-kw diesel-electric generating unit installed on one of the abutments. The gates have been designed for loads resulting from a maximum hydrostatic head of approximately 10 feet occurring during a design hurricane, plus the additional loads resulting from concurrent design waves. Wave forces were determined by assuming a clapotis crest on the outer face of the gate leaf coincident with a clapotis trough on the inner face.

The live load on the gates would be transmitted to the abutments through the four gate arms which are pin connected to each corner of the gate leaf in order to prevent moment transference. The gate arms would be sized to support these axial loads as unbraced main-column members. Secondary bracing would be provided at the mid-span position of the arms to suppress possible vibration. See Plate D-4.

e. Business Center Protection. The supplemental protection for the business center would consist of diking along the lower 3,000 feet of the right or west bank of the Wankinco River, then continuing with wall and dike protection, for a distance of about 490 feet, to high ground on the west side of Main Street, on the west bank of Wareham River about 200 feet below the Route U.S. 6 highway bridge. The dike along the Wankinco River would be of earth fill with rock on the top and riverside slope and gravel on the landside slope. The top would be at an elevation of 13.0 feet msl and have a width of 10 feet. A berm 15-foot wide would be provided on the riverside slope of the dike, at elevation 6.0 feet msl, to increase the stability. Steel sheet piling with concrete cap, with a top elevation of 13.5 feet msl, would be installed at the top of the bank between the railroad bridge and the Route U.S. 6 highway bridge. The closure dike below Route U.S. 6, about 250 feet long, would be of earth fill with rock on the top and riverside slope and gravel on the landward slope. The dike would have a top width of 10 feet at elevation 13.5 feet msl. Stop-log structures would be provided at the crossing of the railroad at the west end of the railroad bridge, at the crossing of Route U.S. 6, at the west end of the Route U.S. 6 bridge, and at the crossing of Main Street near the southern extremity of the protection. See Plate D-5.

f. Pertinent Data. Pertinent data on the selected plan are summarized in Table D-1 on the following page.

TABLE D-1
PERTINENT DATA
HURRICANE PROTECTION PLAN

Wareham-Marion, Massachusetts

Structure	Type (1)	Length (feet)	Top Elev. (ft.msl)	Top Width (feet)	Avg. Height (feet)	Side Slopes
Barrier						
Weweantic R.	A	1,050	21	20	27	1 on 2(2)
Wareham R.	A	4,150	21	20	26	1 on 2(2)
Onset Bay	B	2,800	20	20	25	1 on 2(3)
Dikes						
Power Line	C	4,800	19	10	7	1 on 2
Bass Point	B	900	20-21	10	14	1 on 2
Nobska	B	1,300	20-21	10	9	1 on 2
Long Beach	B	1,300	20-21	10	13	1 on 2
Great Neck	B	900	20	10	7	1 on 2
Burgess	B	1,000	19	10	5	1 on 2
Sias Point	D	1,500	19-20	24	9	1 on 1.5
Sias Point Extension	B	300	19	10	5	1 on 2
Business Ctr.	C	3,000	13	10	13	1 on 2(4)
Business Ctr Extension	C	250	13.5	10	5.5	1 on 2
Wall						
Business Ctr.	E	120	13.5	-	6.5	-

TABLE D - 1 (Cont'd)

Wareham-Marion, Mass.

Navigation Opening	Bottom Width (feet)	Sill Elev. (ft.msl)	Side Slopes	Closure Gates	Size of Gates (feet)
Weweantic R.	55	-11.0	1 on 1.5	-	-
Wareham R.	100	-15.0	1 on 1.5	-	-
Onset Bay	100	-17.0	Vertical	2	20 x 20

Stoplog Structures	Type	Width of Opening (feet)	Height of Opening (feet)
Business Center Ext.	Railroad	30	6
	Highway	60	6
	Highway	30	3

Notes:

(1) Following types pertain to respective barriers and dikes:

A: Earth-filled, rock faced, with rock toe on seaward side
B: Earth-filled, rock-faced
C: Earth-filled, rock on top and outer face, gravel on inner face
D: Earth-filled, rock-faced, with 16-foot wide pavement on top of dike
E: Sheet piling with concrete cap

(2) For slope above mean high water. Below mean high water, on upstream side slope is 1 on 4; on seaward side (rock toe), 1 on 1.5

(3) For slope above mean high water. Slope below mean high water is 1 on 4.

(4) With 15-foot wide berm at elevation 6.0 feet msl on river side.

D-5. SITE GEOLOGY AND FOUNDATION CONDITIONS

a. General. Foundation explorations consisting of drive-sample borings and hand-hammered probings were made along the considered alignments of the Weweantic and Wareham River Barriers, the Onset Bay Barrier, and the Business Center Dike. The locations and logs of explorations appear on Plates D-6, D-7 and D-8. Information concerning land areas is based on geological reconnaissance.

b. Weweantic River Protection. The Weweantic River is a shallow tidal sluice which flows north and south between low sandy morainic ridges. The western ridge probably is rock controlled. Subsurface investigations along the alignment of the Weweantic River Barrier consist of three probings and one boring located as shown on Plate D-6. Granitic gneiss was cored at a depth of 29.8 feet below msl in a boring in the Weweantic River. Boulders of the same material, up to about 10 feet in diameter, are common in the area. Small marshes fringe both river banks north of the alignments. The overburden along the alignment of the barrier and the contiguous Bass Point and Nobska Dikes consists mainly of sandy glacial till overlain in the river by a marine or glacial outwash deposit or variable sands. The variable sands in the river are overlain by a thin layer (less than six feet) of soft or very loose material. Topsoil occurs over most of the land dike alignments.

c. Wareham River Protection. The barrier alignment extends from a terrace-like feature which flanks the southwestern side of Bourne Hill, a 110-foot high sandy drumlin, across the mouth of Wareham River to Nobska Point, a low hill which appears to be sandy morainic in character. The beach south of Nobska Point has been partially stabilized by boulder groins while on the east shore littoral drifting has extended the western side of Indian Neck into a long spit known as Long Beach Point, which is submerged at high water.

Subsurface investigations along the alignment of the Wareham River Barrier consist of six probings, two borings, and two underwater borrow test borings. Overburden along the alignment of the protection consists principally of glacial till overlain by variable sands of marine or glacial outwash origin. Relatively thin layers of topsoil and marsh deposits occur on the surface along the alignment of Long Beach Dike. In the river, the sands are capped by 2 to 10 feet of soft or very loose materials. Bedrock was encountered in the Wareham River channel at an elevation of 55.8 feet below msl.

d. Onset Bay Protection. The two headlands, Burgess Point and Sias Point, at the west and east ends of the barrier alignment, respectively, are indeterminate sand and gravel, perhaps morainic, features. Water depths are shallow and Onset Island, a marine sand feature, may overlie small thicknesses of peat or organic silt. Some harbor mud is known to occur on the bottom of Onset Bay, as indicated by borings made in connection with this study and in connection with highway bridge work at the upper end of the bay. Sias Point shows indications of fairly severe wave erosion, owing to its exposed position near the ship channel.

Subsurface explorations along the alignment of the Onset Bay Barrier consist of seventeen probings and two borings as shown on Plate D-7. The overburden along the alignment of the barrier and the Burgess and Sias Point Dikes consists mainly of marine and glacial outwash deposits of variable sands underlain by glacial till. These sand deposits, which are quite deep in the bay, are covered with 2 to 10 feet of very loose or soft materials. Topsoil covers most of the land dike alignments.

e. Business Center Protection. The alignment of the supplemental dike protection for this area of Wareham follows the west bank of the Wankinco River to and just below its confluence with the Agawam River to form the Wareham River. A railroad branch line which parallels the west bank of the river, landward of the dike alignment, appears to be at least partially on granular fills. The landward side of the railroad embankment appears to have been constructed, in part, on the soft or very loose surficial materials occurring along the river's edge. Although most of this material may have been removed by excavation prior to construction of the embankment, evidence of old slides visible along the river toe of the embankment indicates that the fill was placed directly on the soft material resulting in slides which were repaired during construction by adding sufficient granular fill until a stable condition was obtained.

Subsurface explorations made in connection with this study consist of 18 probings as shown on Plate D-8. The results of four borings made in 1938 by the Commonwealth of Massachusetts, at the southwest abutment of the Route U.S. 6 highway bridge, are also shown on this plate. The overburden along the alignment of the Business Center Dike, consists, in general, of deeply buried glacial till covered by a marine or outwash deposit of variable sands overlain at the river's edge and in the river by a layer of soft or very loose materials and overlain on land by topsoil.

Artificial granular fills have been built along the alignment in part on the sands and in part on the soft or very loose materials. Probings made along the river's edge indicate that the soft or very loose materials occur to depths of as much as 13 feet and one of the probings, made through the toe of the railroad embankment, indicates the presence of soft material under the fill. The borings made for the U.S. 6 Highway bridge, near the southern end of the dike alignment, indicate that relatively thin layers of soft or very loose materials along the river have been covered with several feet of granular fill. It is assumed for design purposes that the overburden along the alignment of the dike consists principally of loose to moderately compact variable sands overlying glacial till at considerable depths and capped along the river's edge with up to 13 feet of soft or very loose materials upon portions of which various fills of granular materials have been placed.

f. Power Line Dike and Great Neck Dike. The alignment of the Power Line Dike traverses a slight depression in what appears to be sandy ground moraine with a thin cover of marsh deposits or topsoil. The marsh deposits in the lower portion of the alignment probably range from two to three feet in thickness. For design purposes it is assumed that the overburden along the alignment consists of variable sands or sandy glacial till capped by topsoil or marsh deposits averaging two feet in depth.

The Great Neck Dike is located on a sand and gravel feature, possibly overlying silt. It is assumed that the average thickness of the topsoil is about one foot.

D-6. AVAILABILITY OF CONSTRUCTION MATERIALS

a. Earth Borrow. Materials suitable for construction of the earth fills are available from undeveloped land areea within haul distances of one to six miles of the structures. The potentially available materials include glacial tills (mainly gravelly silty sand) with less than 25 percent fines; clean coarse to fine and medium to fine sands with generally less than 10 percent fines.

b. Bank-Run Gravel. Geological reconnaissance indicates that there are no significant deposits of gravel in the immediate vicinity of the project which would be suitable for bedding and filter layers. The nearest known source of gravel is at Middleboro, Massachusetts, about 25 miles from the project site.

c. Rock. The nearest operating quarry is in Acushnet, Massachusetts, at a haul distance of approximately 18 miles. Also, there is an inactive quarry, with development possibilities, about 16 miles northwest of the site. Rock from both sources would be of acceptable quality.

d. Aggregates. Crushed quarry stone and processed natural sand and gravel aggregates, which have been tested and approved for the New Bedford-Fairhaven, Massachusetts, Hurricane Protection Project, are available within a haul distance of 25 miles.

D-7. SELECTION OF EMBANKMENT SECTIONS

a. Foundation Preparation. In general, the foundation for the barrier embankments consist of granular soils with occasional cappings of soft organic silt of varying thickness. Estimates and designs are based on removal of the organic silt deposits prior to construction of the embankment.

The foundation at the site of the Weweantic River Barrier is characterized by a surface deposit of very loose fine sand up to about six feet thick. This deposit of sand will not be removed but will be displaced or confined by the placement of rock and other embankment materials. On the alignment of the Onset Bay Barrier, west of Onset Island, it appears that there are two extensive deposits of silt separated by a layer of sand and capped by varying thicknesses of sand and occasional shallow layers of soft surface materials. Where the existing bottom is at an elevation of 10 feet or less below mean sea level, it is planned to remove only the soft surficial materials. In areas with depths greater than 10 feet below mean sea level, the soft surficial materials and the upper layer of silt will both be removed.

At the riverside toe of the Business Center Dike there is a considerable depth of soft materials. A stable embankment can be obtained by the displacement of about four cubic yards of this soft material per foot of dike by the method described in paragraph D-7b (3).

The land dike foundations, in general, consist of granular soils with cappings of topsoil or marsh deposits or variable thickness. Construction of the dikes will require the excavation of one to two feet or organic overburden. The estimate for the Weweantic River Barrier is based on no foundation excavation but does include an allowance for three feet of combined settlement and displacement of foundation material over the entire length of the barrier. The estimates for the Wareham River Barrier include an allowance for six feet of excavation and sand backfill for a length of 2,000 feet and two feet of excavation for a length of 300 feet. The Onset Bay barrier estimate is based on five to eight feet of foundation excavation for about 1,400 feet of length, and two feet of excavation for 700 feet of length.

b. Embankments.

(1) General. The embankment sections have been selected on the basis of the availability and economy of fill materials, construction considerations, foundation conditions, seepage control requirements, and the effect of wave action. Two general types of embankment are required: (1) land dike embankments constructed on dry land, and (2) barrier embankments constructed in water. The Business Center Dike, while essentially a land dike, is considered separately since it falls into both categories.

(2) Land Dikes. The land dike embankments consist principally of compacted earth fill material obtained from deposits of silty sand or sandy glacial till located in the vicinity of the project. A layer or armor or cover stone, with layers of gravel and stone bedding, provide protection against wave action and erosion. Studies of alternate sections, which varied chiefly in the use of materials other than compacted earth fill, indicated that the selected section was the most economical and feasible.

(3) Barriers. The land dike section discussed above has been selected for the portion of the barrier embankment above high tide level or above the surface of any dumped fill that is above high tide. Two sections were selected for the lower portions of the barriers. For the Onset Bay Barrier embankment, which is not exposed to severe wave action, the lower portion of the embankment consists of dumped sand fill obtained from deposits of clean sands northeast of the village of Onset and layers of rock slope protection and gravel as required for protection against wave action, erosion, and for seepage control. In the case of the Weweantic River Barrier and the Wareham River Barrier, which are exposed to severe wave action, the lower portion of the embankment is similar to that for the Onset Bay Barrier except for the addition of a heavy rock fill toe on the ocean side. Other sections were considered for the lower portions of the barrier embankments including sections of dumped earth fill and dredged material. It was found, however, that only the dumped sand fill could be placed in water to slopes as steep as one vertical on four horizontal and develop and angle of friction in order of 30 degrees after placement. It was determined that the alternate sections, although built of less costly materials, required additional quantities of material, owing to the need for berms and flatter slopes, and would be more costly than the selected sections.

(4) Business Center Dike. The selected section for this dike consists of dumped earth fill up to an elevation of 4.0 feet msl, a 15-foot berm on the river side, and a typical land dike section above the 4-foot elevation. It is anticipated that the dumped earth-fill portion of the section will displace enough of

the soft foundation materials at the toe, in the river to provide a stable embankment. Alternate embankment sections, including a land dike section constructed subsequent to removal of the soft foundation materials, and sections with substantial berms floated upon the soft materials were studied and found to be more costly than the selected sections.

c. Construction. The embankment sections for the barriers have been designed to permit use of land-based construction equipment. It has been assumed that all fills placed in water, including dumped sand fill and rock toes, will be constructed by end dumping methods followed immediately, in the case of the dumped fill, by the placement of gravel and armor stone layers to minimize the loss of materials. Sections of compacted fill will be constructed by the usual method.

d. Abutment Foundations. The abutment for the navigation openings for the Weweantic River and Wareham River Barriers will consist of rock fill for which minor settlement will not be detrimental. At the Wareham River navigation opening the soft foundation material, extending to a depth of about 26 feet below mean sea level, will be excavated. At the Onset Bay Barrier opening it is necessary to keep the settlement of the concrete abutments for the partial gates to less than six inches. To meet this requirement, the base of each abutment has been set at an elevation of 23 feet below msl and the foundation sand compacted by driving 20-foot compaction piles on 10-foot centers.

D-8. MODIFICATIONS TO SEWERAGE AND DRAINAGE FACILITIES.

Construction of the recommended hurricane protection plan would entail no modification to any existing sanitary sewerage facilities. All existing drainage lines passing under the project structures would be strengthened or replaced where necessary to carry the added weight of the structures. All such lines would be suitably gated to prevent the entry of tidal-flood waters. A 48-inch concrete culvert passing under the New Haven Railroad tracks and emptying into the Wankinco River would be extended under the Business Center Dike and provided with a mechanically operated sluice gate for closure during hurricanes. Gated culverts would be provided at two small drainage ditches crossing the present alignment of the Power Line Dike.

D-9. LANDS AND DAMAGES

The cost of furnishing necessary lands, easements, and rights-of-way, which would be one requirement of local cooperation, has been estimated on the basis of a field reconnaissance and the application of current market values for the locality. No lands would be acquired in fee. Permanent easements would be acquired on about 23 acres and temporary easements on 16 acres.

D-10. RELOCATIONS

The construction of the protection plan would not require the relocation of any highways, railroads, or water lines other than the raising of about 1,500 feet of Robinwood Road in Onset to the top of Sias Dike. Three fire hydrants, four catch basins and 12 wooden power poles located within the construction area would require relocation.

D-11. PLAN OF CONSTRUCTION

The structures in the protection plan for the Wareham-Marion area would require about two years to construct. It is anticipated that channel pavement would be one of the early steps of construction in order to allow for continuous passage of boats and to prevent scour in the channel as the barriers approach completion. Each barrier would be brought to grade as rapidly as possible, consistent with efficient construction procedures, to avoid damage and loss of fill in the event of a serious storm. The construction schedule would be generally as follows:

a. During the first year, the Weweantic and Wareham River Barriers and contiguous dikes would be completed. This would afford partial protection to flooded areas along the Weweantic and Wareham Rivers at the end of the first year.

b. During the second year, the Onset Bay Barrier and its closure dikes, and the Power Line, Great Neck, and Business Center Dikes would be constructed and placed in operation.

BASIS OF ESTIMATES OF FIRST COST AND ANNUAL COSTS

D-12. COST ESTIMATES

Estimates of quantities have been made on the basis of sections and details shown on Plates D-2 through D-5. Fill and rock quantities are "in place" measurements. The unit costs for fills include the costs of borrow, haul, and placement. Excavation costs include disposal of the material.

D-13. UNIT PRICES

Unit prices, which are on a 1961 price level, are based on averages for similar types of construction in New England, and where applicable, similar construction in other parts of the country. Adjustments have been made for the availability and locations of materials required, and the most likely methods of handling and placement. The adopted unit prices include allowances for items such as the improvement and restoration of existing roads used for access during construction which do not appear as separate items in the cost estimate.

D-14. CONTINGENCIES, ENGINEERING AND OVERHEAD

The estimate includes a 15 percent allowance to cover contingencies. The costs for engineering, design, supervision, and administration, see Table D-2, are estimated lump sums based on experience on similar projects. The cost for engineering and design include $10,000 for model flume tests of flows through the navigation openings.

D-15. LOCAL CONTRIBUTIONS AND COOPERATION

It is proposed that local interests contribute in cash toward the first cost of the project an amount presently estimated at $1,518,000. This amount is equivalent to 30 percent of the first cost of the project less credit for furnishing lands, easements and rights-of-way and accomplishing necessary relocations of utilities, see Table D-3.

D-16. ANNUAL COSTS

The estimate of annual charges is based on interest at 2.625 percent on the Federal investment in the project and 3.5 percent on the non-Federal investment, and amortization of the investments over a period of 100 years. The total investment includes item of interest for one year, for one-half of the total construction period of 2 years, at 2.625 percent on the Federal costs and 3.5 percent on the non-Federal costs. An allowance of $2,000 for the loss of taxes on lands is included in the annual cost. Costs of maintenance and operation of the project and major replacements are based on a knowledge of the site and costs of similar projects.

FIRST COSTS AND ANNUAL COSTS

D-17. FIRST COSTS

The estimated first cost of the protection plan is $5,445,000 of which $3,811,500 would be borne by the United States. Local interests would contribute in cash $1,518,500, accomplish all necessary relocations of utilities at an estimated cost of $15,000 and provide lands, easements and rights-of-way at an estimated cost of $100,000 for a total local first cost of $1,633,500. Detailed breakdowns of the estimate, by principal features of the work, and by quantities and unit price, are shown in Table D-2. Allocations of costs are shown in Table D-3.

D-18. ANNUAL COSTS

The total annual charges for the Wareham-Marion protection plan amount to an estimated $192,000. Of this amount, $114,000 represents Federal annual charges and $78,000 non-Federal. The determination of annual charges is shown in Table D-3.

TABLE D-2

ESTIMATED FIRST COSTS
(1961 Price Level)

HURRICANE PROTECTION PLAN

Wareham-Marion, Mass.

SUMMARY

Weweantic River Barrier and Dikes	$ 726,000	
Wareham River Barrier and Dike	1,739,000	
Onset Bay Barrier and Dikes	1,566,000	
Power Line Dike	155,000	
Great Neck Dike	51,000	
Business Center Dike and Wall	290,000	
Subtotal	$ 4,527,000	
Engineering and Design	408,000	408
Supervision and Administration	395,000	− 45
Subtotal	$ 5,330,000	363 + 40
Relocation of Utilities	15,000	403
Lands and Damages	100,000	Say 400
Total First Cost	$ 5,445,000	
Aids to Navigation (U.S. Coast Guard)	10,000	
Preauthorization Studies	40,000	
Total Project Cost	$ 5,495,000	

TABLE D-2 (Cont'd)

ESTIMATED FIRST COSTS
(1961 Price Level)

HURRICANE PROTECTION PLAN

Wareham-Marion, Mass.

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
Weweantic River Barrier and Dikes				
Preparation of site	1	job	L.S.	$ 2,000
Earth excavation, common	17,000	c.y.	1.00	17,000
Earth excavation, underwater	10,000	c.y.	1.20	12,000
Earth fill, dumped	30,000	c.y.	1.30	39,000
Earth fill, compacted	36,000	c.y.	1.50	54,000
Gravel, barrier and dike	12,000	c.y.	3.75	45,000
Gravel, channel paving	3,000	c.y.	7.00	21,000
Rock, cover and bedding	45,000	c.y.	7.00	315,000
Rock fill, barriers	20,000	c.y.	4.00	80,000
Rock, channel paving	4,000	c.y.	9.00	36,000
Fender System	1	job	L.S.	10,000
		Subtotal		$ 631,000
Contingencies				95,000
Total - Weweantic River Barrier and Dikes				$ 726,000
Wareham River Barrier and Dike				
Preparation of site	1	job	L.S.	$ 2,000
Earth excavation, common	8,000	c.y.	1.00	8,000
Earth excavation, underwater	85,000	c.y.	1.20	102,000
Earth fill dumped	150,000	c.y.	1.30	195,000
Earth fill, compacted	84,000	c.y.	1.50	126,000
Gravel, barrier and dike	30,000	c.y.	3.75	112,500
Gravel, channel paving	4,000	c.y.	7.00	28,000
Rock, cover and bedding	97,000	c.y.	7.00	679,000
Rock, channel paving	5,500	c.y.	9.00	49,500
Rock fill, barriers	50,000	c.y.	4.00	200,000
Fender System	1	job	L.S.	10,000
		Subtotal		$1,512,000
Contingencies				227,000
Total - Wareham River Barrier and Dike				$1,739,000

TABLE D-2 (Cont'd)

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
Onset Bay Barrier and Dikes				
Preparation of site	1	job	L.S.	$ 3,000
Earth excavation, common	6,000	c.y.	1.00	6,000
Earth excavation, underwater	90,000	c.y.	1.20	108,000
Earth fill, dumped	150,000	c.y.	1.30	195,000
Earth fill, compacted	80,000	c.y.	1.50	120,000
Gravel, dikes and barrier	24,000	c.y.	3.75	90,000
Gravel, channel paving	4,000	c.y.	7.00	28,000
Rock, cover and bedding	60,000	c.y.	7.00	420,000
Rock fill, barrier	6,000	c.y.	4.00	24,000
Rock, channel paving	5,400	c.y.	9.00	54,000
Partial Closure Gates				
Sheet steel piling	170	tons	300.00	51,000
Concrete tremie	3,000	c.y.	30.00	90,000
Concrete, mass	1,200	c.y.	35.00	42,000
Compaction piling	1	job	L.S.	6,000
Gates & machinery	1	job	L.S.	95,000
Fender system	1	job	L.S.	10,000
Road pavement	4,000	s.y.	3.00	12,000
Guard rail	4,000	l.f.	2.00	8,000
			Subtotal	$1,362,000
Contingencies				204,000
Total - Onset Bay Barrier and Dikes				$1,566,000
Power Line Dike				
Preparation of site	1	job	L.S.	$ 1,000
Earth excavation, common	19,000	c.y.	1.00	19,000
Earth fill, compacted	30,000	c.y.	1.50	45,000
Gravel	7,200	c.y.	3.75	27,000
Rock, cover and bedding	6,000	c.y.	7.00	42,000
Drainage facilities	1	c.y.	L.S.	1,000
			Subtotal	$ 135,000
Contingencies				20,000
Total - Power Line Dike				$155,000

TABLE D-2 (Cont'd)

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
Great Neck Dike				
Preparation of site	1	job	L.S.	$ 500
Earth excavation, common	3,000	c.y.	1.00	3,500
Earth fill, compacted	4,000	c.y.	1.50	6,000
Gravel	1,600	c.y.	3.75	6,000
Rock, cover & bedding	4,200	c.y.	7.00	28,000
			Subtotal	$ 44,000
Contingencies				7,000
Total - Great Neck Dike				$ 51,000
Business Center Dike and Wall				
Preparation of site	1	job	L.S.	$ 2,000
Earth excavation, common	1,000	c.y.	1.00	1,000
Earth fill, compacted	70,000	c.y.	1.50	105,000
Gravel	7,200	c.y.	3.75	27,000
Rock, cover and bedding	7,500	c.y.	7.00	52,500
Stoplog structures				
30' wide x 3' high	1	job	L.S.	$ 3,000
60' wide x 6' "	1	job	L.S.	15,000
30' wide x 7' "	1	job	L.S.	8,000
Sheet pile wall	120	l.f.	2.00	24,000
Modification to drainage	1	job	L.S.	15,000
			Subtotal	$ 252,500
Contingencies				37,500
Total - Business Center Protection				$ 290,000
Relocation of Utilities				
Relocation of utilities	1	job	L.S.	$ 11,000
Contingencies				2,000
			Subtotal	$ 13,000
Engineering and design (local)				1,000
				$ 14,000
Supervision and administration (local)				1,000
Total Cost - Relocations				$ 15,000

TABLE D-2 (Cont'd)

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
	Lands and Damages			
Permanent easements	23	acres	L.S.	$ 49,000
Temporary easements	16	acres	L.S.	4,000
Permanent access rights			L.S.	8,000
				$ 61,000
Contingencies				9,000
				$ 70,000
Acquisition costs				30,000
Total Costs - Lands and Damages				$ 100,000

TABLE D-3

ESTIMATED ANNUAL COSTS
(1961 Price Level)

HURRICANE PROTECTION PLAN

Wareham-Marion, Mass.

Federal Investment

First cost	$3,811,500 (1)
Preauthorization studies	40,000
Aids to navigation	10,000 (2)
Subtotal	3,861,500
Interest during construction	101,500
Total Federal Investment	$3,963,000

Federal Annual Costs

Interest on investment (2.625%)	$ 104,000
Amortization (0.213%)	9,000
Maintenance and operation, navigation aids	1,000 (2)
Total Federal Annual Cost	$114,000

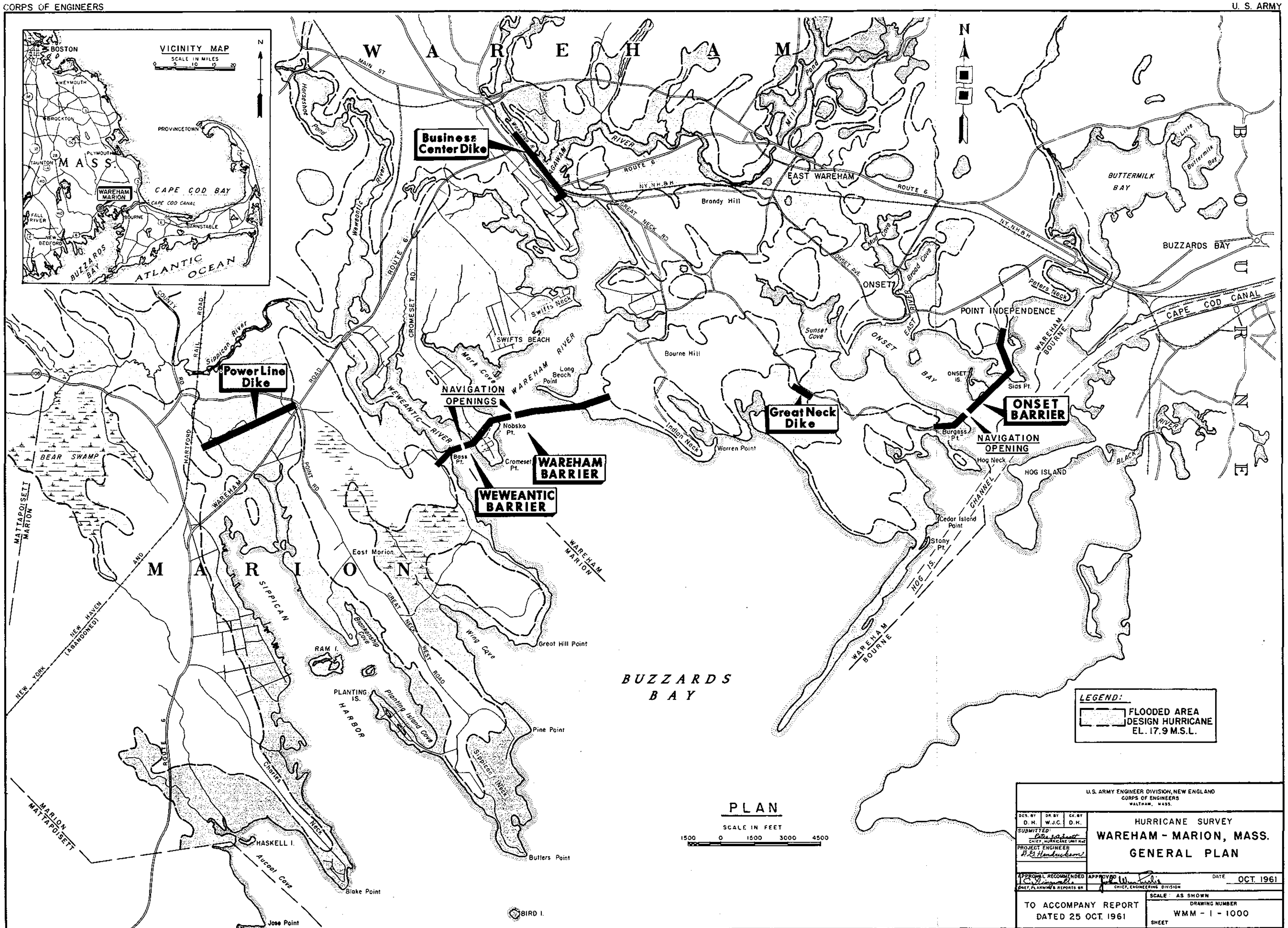
Non-Federal Investment

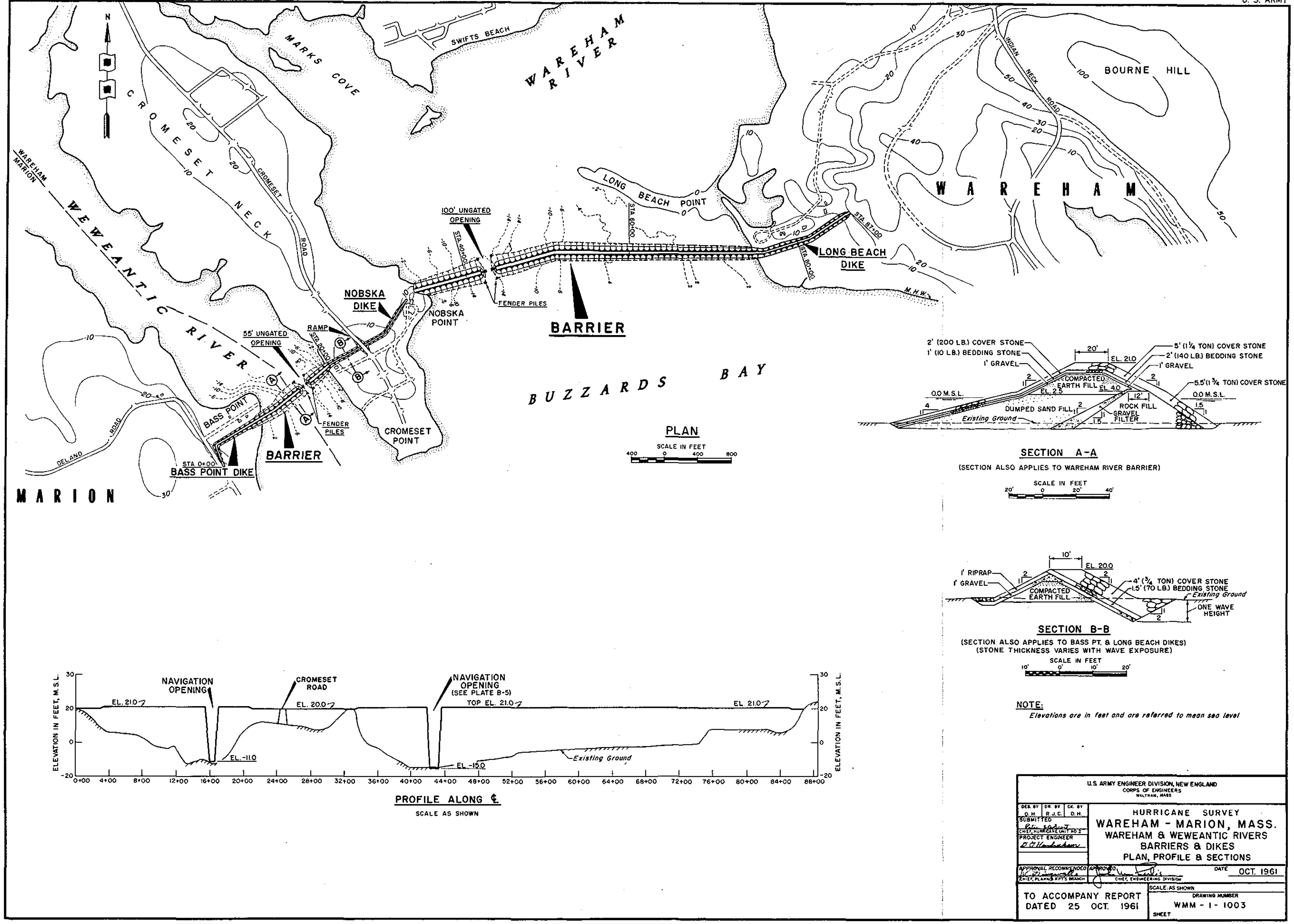
Contributed funds	$1,518,000
Relocations of utilities	15,000
Lands, easements, and rights-of-way	100,000
Total Non-Federal First Cost	$1,633,500 (3)
Interest during construction	57,500
Total Non-Federal Investment	$1,691,000

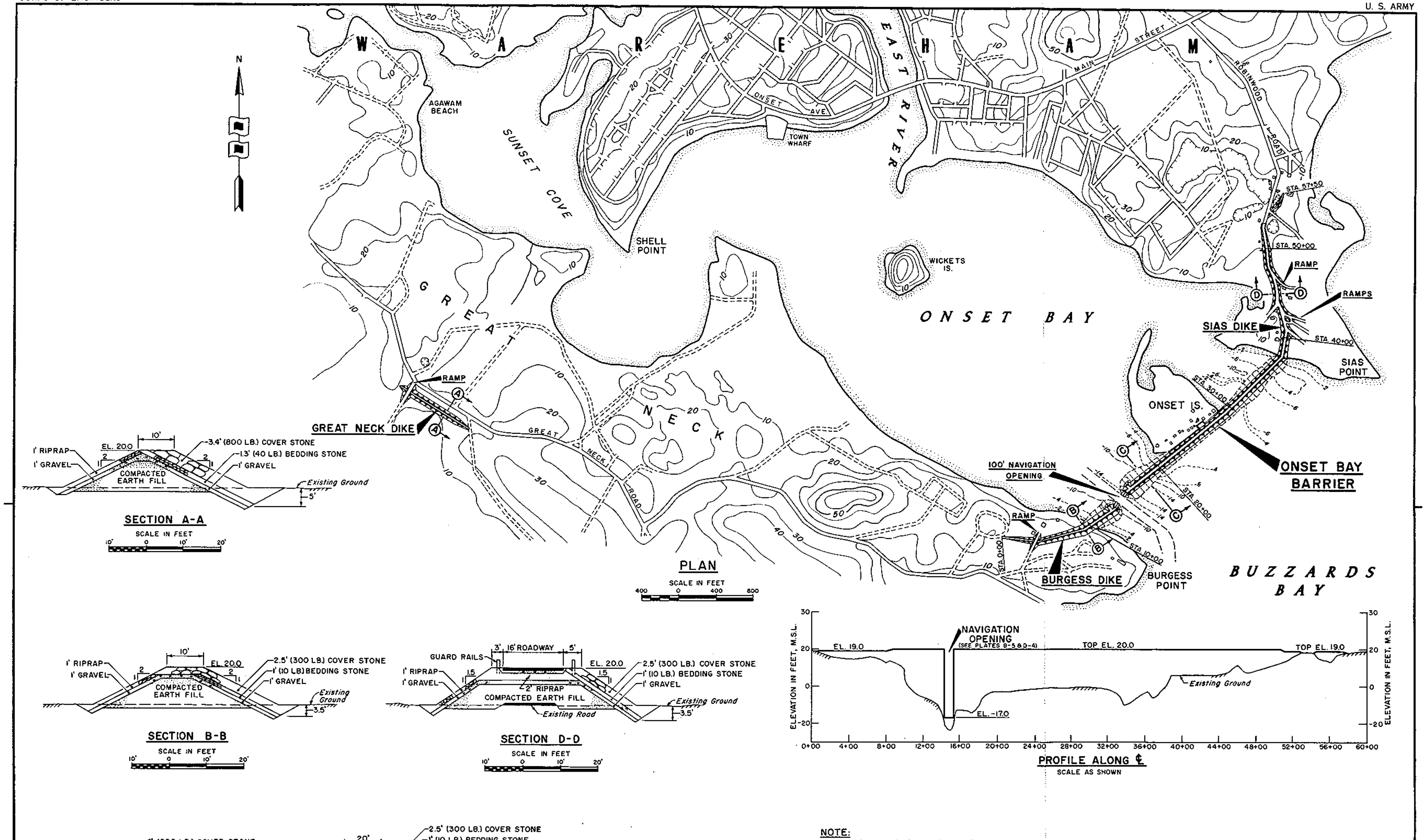
Non-Federal Annual Costs

Interest on investment (3.5%)		$ 59,000
Amortization (0.116%)		2,000
Major replacements		2,000
Maintenance and operation		
Salaries	4,000	
Embankment and general	6,000	
Concrete features	1,000	
Gates and accessories	2,000	13,000
Estimated tax losses		2,000
Total Non-Federal Annual Costs		$ 78,000
Total Annual Costs		$192,000

(1) 70% of $5,445,000 First Cost
(2) By U.S. coast Guard
(3) 30% of $5,445,000 First Cost


VICINITY MAP
SCALE IN MILES
BOSTON
WEYMOUTH
BROCKTON
PROVINCETOWN
PLYMOUTH
TAUNTON
MASS.
CAPE COD BAY
WAREHAM MARION
CAPE COD CANAL
BOURNE
BARNSTABLE
FALL RIVER
NEW BEDFORD
BUZZARDS BAY
ATLANTIC OCEAN
W A R E H A M
M A R I O N
B O U R N E
Business Center Dike
Power Line Dike
NAVIGATION OPENINGS
WAREHAM BARRIER
WEWEANTIC BARRIER
Great Neck Dike
ONSET BARRIER
NAVIGATION OPENING
EAST WAREHAM
Brandy Hill
BUTTERMILK BAY
BUZZARDS BAY
POINT INDEPENDENCE
CAPE COD CANAL
ONSET
ONSET BAY
Bourne Hill
SWIFTS BEACH
Swifts Neck
WAREHAM RIVER
WEWEANTIC RIVER
Nobska Pt.
Cromeset Pt.
Bass Pt.
Indian Neck
Warren Point
Burgess Pt.
Sias Pt.
Hog Neck
HOG ISLAND
Cedar Island Point
Stony Pt.
HOG IS. CHANNEL
BEAR SWAMP
Sippican River
East Marion
RAM I.
PLANTING IS.
SIPPICAN HARBOR
Great Hill Point
Pine Point
Butlers Point
Blake Point
Jose Point
HASKELL I.
Aucoot Cove
BIRD I.
BUZZARDS BAY
LEGEND:
FLOODED AREA DESIGN HURRICANE EL. 17.9 M.S.L.
PLAN
SCALE IN FEET
1500 0 1500 3000 4500
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY D.H. DR. BY W.J.C. CK. BY D.H.
SUBMITTED: CHIEF, HURRICANE UNIT No2
PROJECT ENGINEER
HURRICANE SURVEY
WAREHAM - MARION, MASS.
GENERAL PLAN
APPROVAL RECOMMENDED CHIEF, PLANNING & REPORTS BR
APPROVED CHIEF, ENGINEERING DIVISION
DATE OCT. 1961
SCALE: AS SHOWN
TO ACCOMPANY REPORT DATED 25 OCT. 1961
DRAWING NUMBER WMM - 1 - 1000
SHEET


SWIFTS BEACH
MARKS COVE
WAREHAM RIVER
CROMESET
CROMESET NECK
CROMESET NECK ROAD
WAREHAM
MARION
WEWEANTIC RIVER
BOURNE HILL
INDIAN NECK ROAD
WAREHAM
LONG BEACH POINT
100' UNGATED OPENING
STA. 40+00
STA. 60+00
STA. 87+00
STA. 80+00
LONG BEACH DIKE
M.H.W.
NOBSKA DIKE
NOBSKA POINT
FENDER PILES
BARRIER
RAMP
55' UNGATED OPENING
STA. 20+00
BUZZARDS BAY
BASS POINT
FENDER PILES
CROMESET POINT
DELANO ROAD
STA. 0+00
BASS POINT DIKE
BARRIER
MARION
PLAN
SCALE IN FEET
400 0 400 800
2' (200 LB.) COVER STONE
1' (10 LB.) BEDDING STONE
1' GRAVEL
20'
EL. 21.0
5' (1 1/4 TON) COVER STONE
2' (140 LB.) BEDDING STONE
1' GRAVEL
COMPACTED EARTH FILL
EL. 2.5
EL. 4.0
12'
5.5' (1 3/4 TON) COVER STONE
0.0 M.S.L.
DUMPED SAND FILL
ROCK FILL
GRAVEL FILTER
Existing Ground
SECTION A-A
(SECTION ALSO APPLIES TO WAREHAM RIVER BARRIER)
SCALE IN FEET
20' 0 20' 40'
10'
EL. 20.0
1' RIPRAP
1' GRAVEL
COMPACTED EARTH FILL
4' (3/4 TON) COVER STONE
1.5' (70 LB.) BEDDING STONE
Existing Ground
ONE WAVE HEIGHT
SECTION B-B
(SECTION ALSO APPLIES TO BASS PT. & LONG BEACH DIKES)
(STONE THICKNESS VARIES WITH WAVE EXPOSURE)
SCALE IN FEET
10' 0' 10' 20'
NOTE:
Elevations are in feet and are referred to mean sea level
NAVIGATION OPENING
CROMESET ROAD
NAVIGATION OPENING (SEE PLATE B-5)
EL. 21.0
EL. 20.0
TOP EL. 21.0
EL. 21.0
EL. -11.0
EL. -15.0
Existing Ground
ELEVATION IN FEET, M.S.L.
0+00 4+00 8+00 12+00 16+00 20+00 24+00 28+00 32+00 36+00 40+00 44+00 48+00 52+00 56+00 60+00 64+00 68+00 72+00 76+00 80+00 84+00 88+00
PROFILE ALONG ℄
SCALE AS SHOWN
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY D.H.
DR. BY R.J.C.
CK. BY D.H.
SUBMITTED
CHIEF, HURRICANE UNIT NO 2
PROJECT ENGINEER
HURRICANE SURVEY
WAREHAM - MARION, MASS.
WAREHAM & WEWEANTIC RIVERS
BARRIERS & DIKES
PLAN, PROFILE & SECTIONS
APPROVAL RECOMMENDED
CHIEF, PLANNG & RPT'S BRANCH
APPROVED
CHIEF, ENGINEERING DIVISION
DATE OCT. 1961
TO ACCOMPANY REPORT DATED 25 OCT. 1961
SCALE: AS SHOWN
DRAWING NUMBER
WMM - 1 - 1003
SHEET



NOTE:
Elevations are in feet and are referred to mean sea level.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY
D.H.	R.J.C.	D.H.

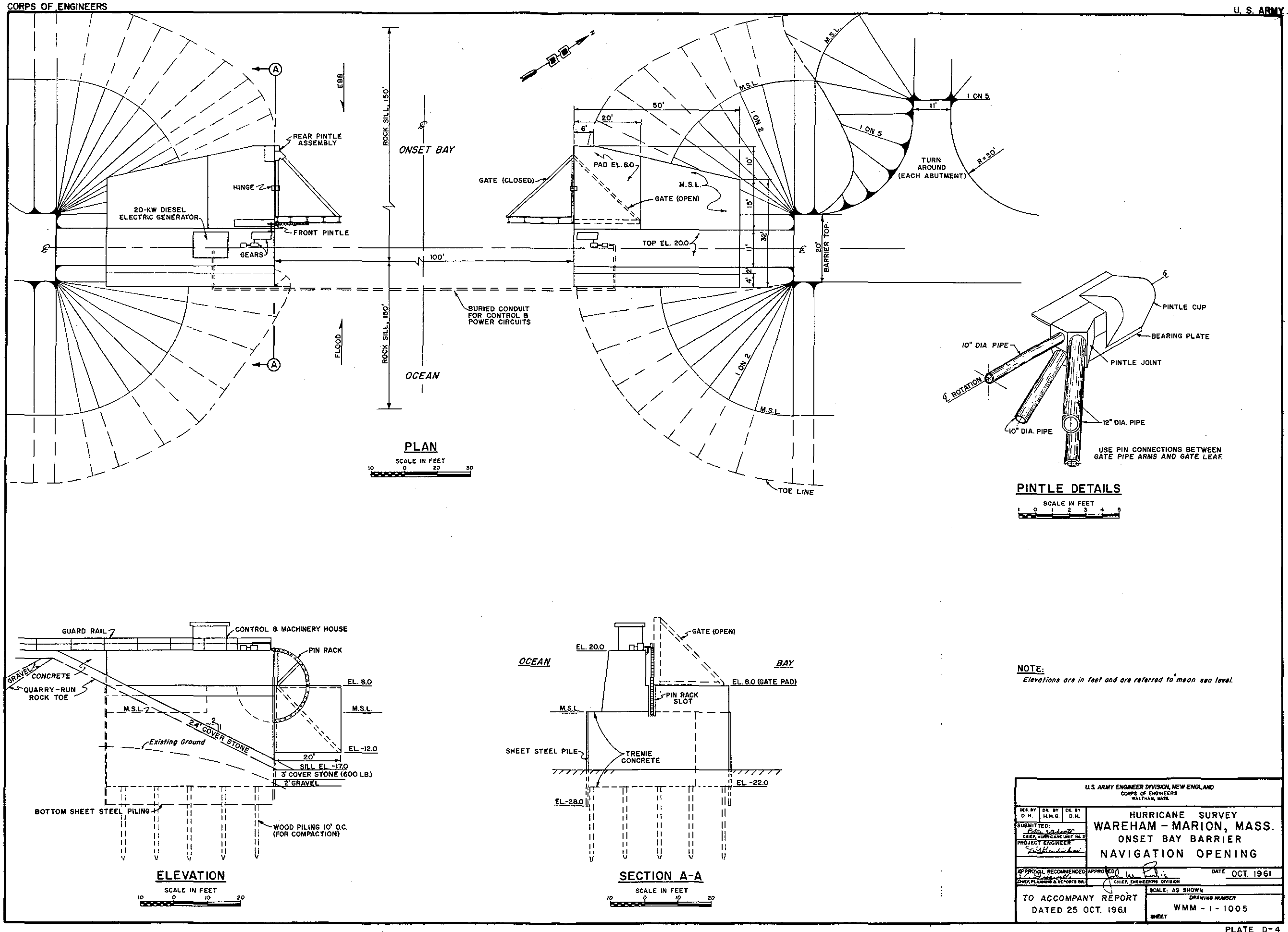
SUBMITTED
CHIEF, HURRICANE UNIT NO. 2
PROJECT ENGINEER

HURRICANE SURVEY
WAREHAM - MARION, MASS.
ONSET BAY
BARRIER & DIKES
PLAN, PROFILE & SECTIONS

APPROVAL RECOMMENDED — CHIEF, PLANNING & RPTS. BRANCH
APPROVED — CHIEF, ENGINEERING DIV.
DATE OCT. 1961
SCALE: AS SHOWN

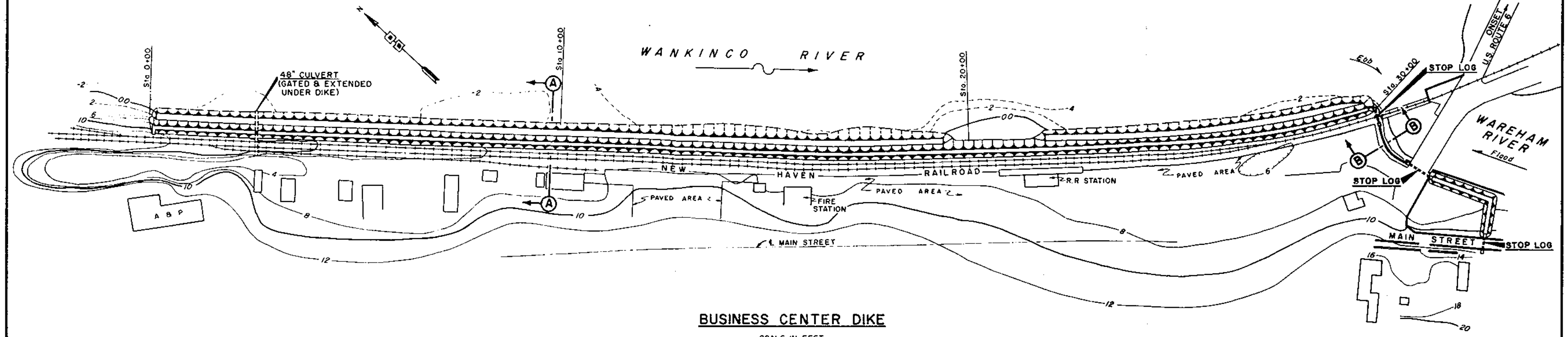
TO ACCOMPANY REPORT
DATED 25 OCT. 1961

DRAWING NUMBER
WMM - 1 - 1004
SHEET


CORPS OF ENGINEERS
U. S. ARMY
REAR PINTLE ASSEMBLY
HINGE
20-KW DIESEL ELECTRIC GENERATOR
FRONT PINTLE
GEARS
EBB
FLOOD
ROCK SILL, 150'
ONSET BAY
OCEAN
100'
BURIED CONDUIT FOR CONTROL & POWER CIRCUITS
GATE (CLOSED)
PAD EL. 8.0
M.S.L.
GATE (OPEN)
TOP EL. 20.0
50'
20'
6'
1 ON 2
1 ON 5
11'
TURN AROUND (EACH ABUTMENT)
R=30'
BARRIER TOP
TOE LINE
PLAN
SCALE IN FEET
PINTLE CUP
BEARING PLATE
10" DIA. PIPE
PINTLE JOINT
ROTATION
12" DIA. PIPE
USE PIN CONNECTIONS BETWEEN GATE PIPE ARMS AND GATE LEAF.
PINTLE DETAILS
GUARD RAIL
CONTROL & MACHINERY HOUSE
PIN RACK
GRAVEL
CONCRETE
QUARRY-RUN ROCK TOE
EL. 8.0
M.S.L.
24" COVER STONE
Existing Ground
EL. -12.0
SILL EL. -17.0
3' COVER STONE (600 LB.)
2' GRAVEL
BOTTOM SHEET STEEL PILING
WOOD PILING 10' O.C. (FOR COMPACTION)
ELEVATION
GATE (OPEN)
EL. 20.0
OCEAN
BAY
EL. 8.0 (GATE PAD)
PIN RACK SLOT
SHEET STEEL PILE
TREMIE CONCRETE
EL. -22.0
EL. -28.0
SECTION A-A
NOTE:
Elevations are in feet and are referred to mean sea level.
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
HURRICANE SURVEY
WAREHAM - MARION, MASS.
ONSET BAY BARRIER
NAVIGATION OPENING
DATE OCT. 1961
SCALE: AS SHOWN
TO ACCOMPANY REPORT DATED 25 OCT. 1961
WMM - 1 - 1005
PLATE D-4

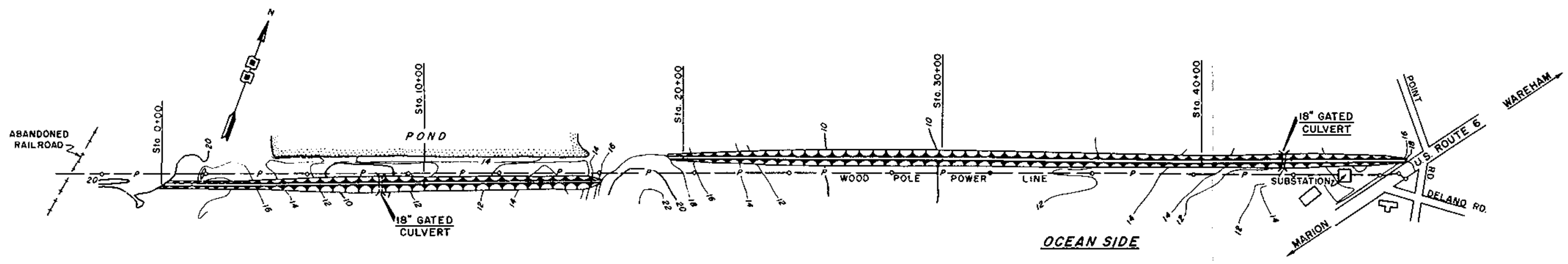
CORPS OF ENGINEERS

U. S. ARMY



BUSINESS CENTER DIKE

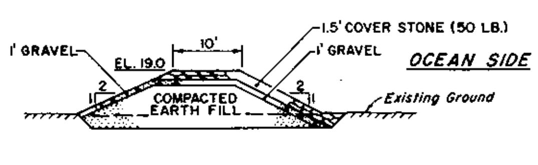
SCALE IN FEET 100' 0 100' 200'



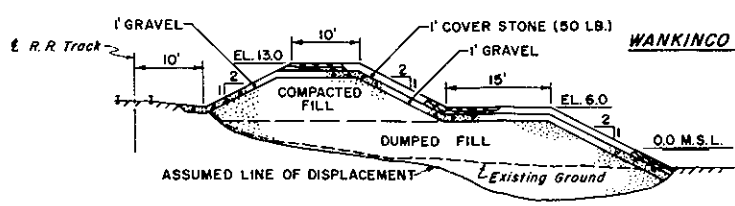
POWER LINE DIKE

SCALE IN FEET 200' 0 200' 400'

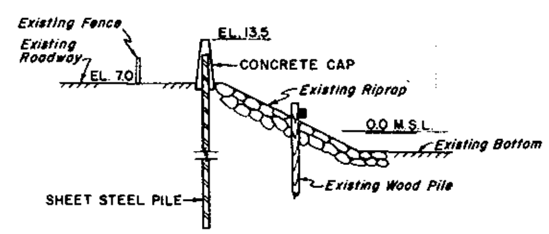
NOTES:
See Plate D-1 for Dike locations.
Elevations are in feet and are referred to M.S.L.



TYPICAL SECTION
(POWER LINE DIKE)
SCALE IN FEET 10 0 10 20



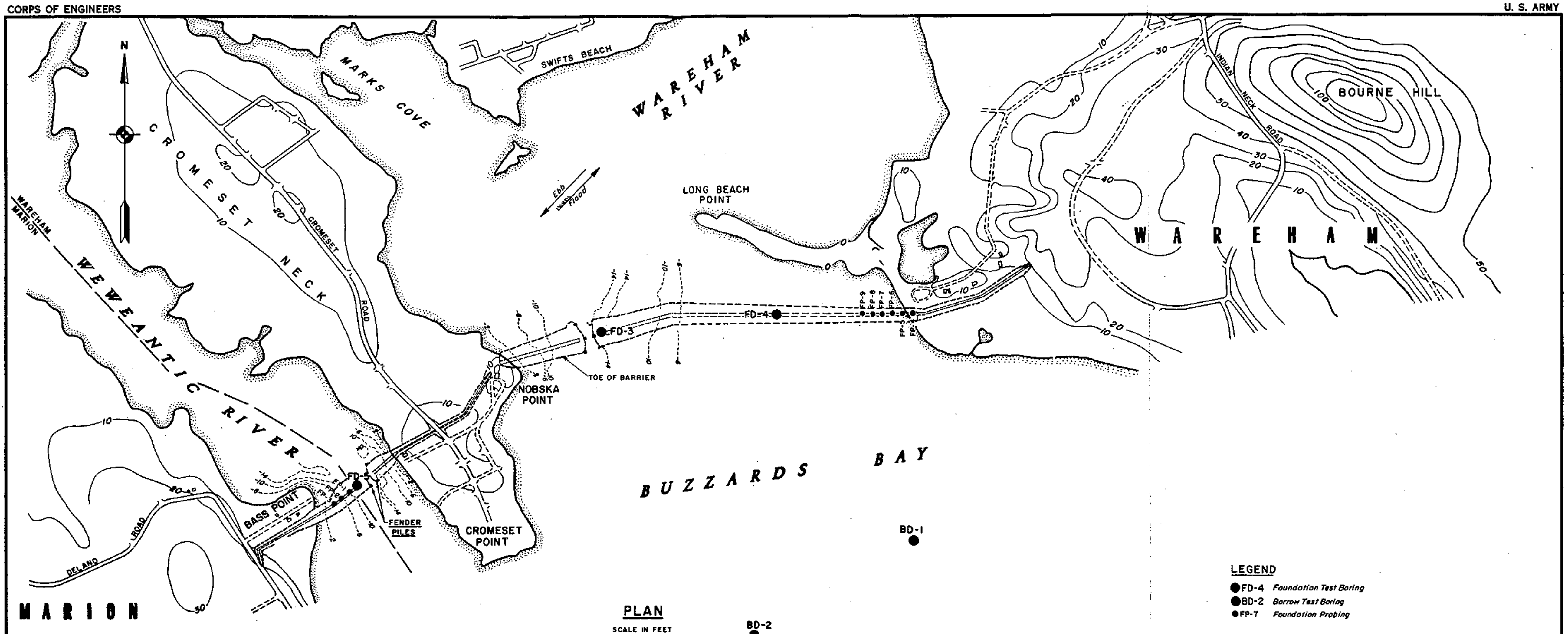
SECTION A-A
(BUSINESS CENTER DIKE)
SCALE IN FEET 10 0 10 20



SECTION B-B
(BUSINESS CENTER DIKE)
SCALE IN FEET 10 0 10 20

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.	
DES. BY D.H. · DR. BY R.J.C. · CK. BY D.H. SUBMITTED CHIEF, HURRICANE UNIT NO. 2 PROJECT ENGINEER	HURRICANE SURVEY WAREHAM - MARION, MASS. BUSINESS CENTER & POWER LINE DIKES PLANS & SECTIONS
APPROVAL RECOMMENDED CHIEF, PLANN. DEPT'S BRANCH	APPROVED CHIEF, ENGINEERING DIV. DATE OCT. 1961
TO ACCOMPANY REPORT DATED 25 OCT 1961	SCALE: AS SHOWN DRAWING NUMBER WMM - 1 - 1006 SHEET

PLATE D-5



PLAN

SCALE IN FEET 400 0 400 800

LEGEND

- ● FD-4 *Foundation Test Boring*
- ● BD-2 *Borrow Test Boring*
- ● FP-7 *Foundation Probing*

NOTES

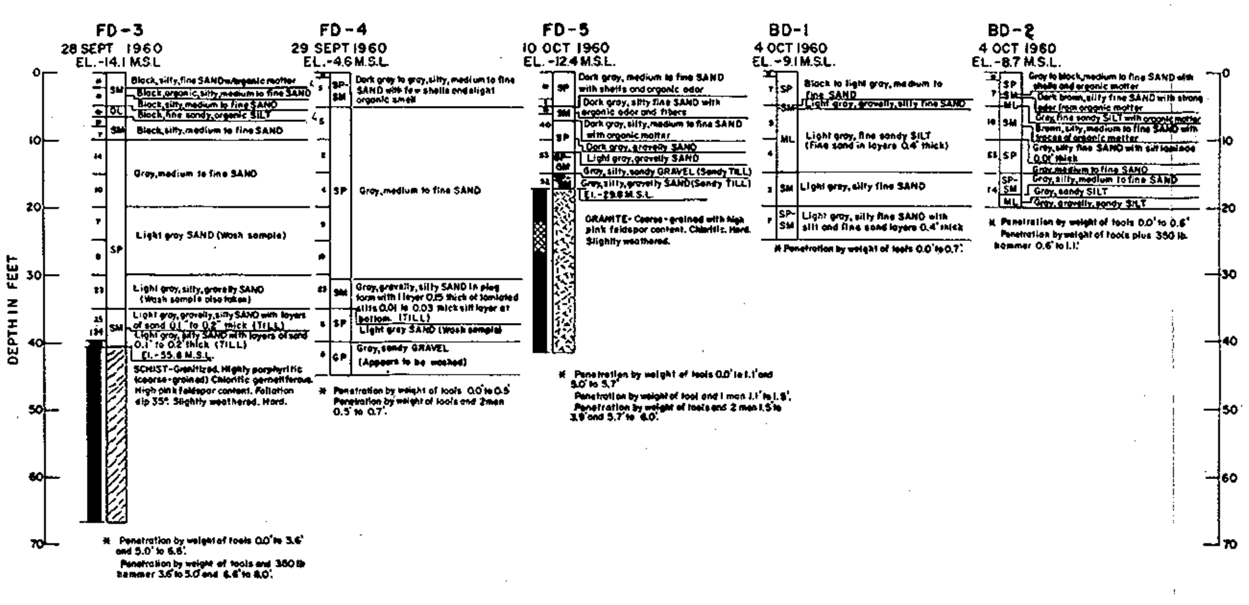
All elevations refer to Mean Sea Level
Contours are in feet

PROBING TABLE

PROBING NUMBER	CORRECTED SOUNDINGS (M.S.L.)	PENETRATION DEPTH (1 MAN)	PENETRATION DEPTH (2 MEN)	PENETRATION DEPTH AND BLOWS/FT REQ. (18LB. HAMMER)							
FP- 1	4.6 FEET	0.0 - 2.2	2.2 - 3.4	3.4 - 4.4	8	-	-	-	-	-	-
FP- 2	5.2	0.0 - 1.7	1.7 - 1.8	1.8 - 2.8	42	-	-	-	-	-	-
FP- 3	4.6	0.0 - 3.5	3.5 - 3.7	3.7 - 4.6	42	-	-	-	-	-	-
FP- 4	+3.9	0.0 - 0.3	0.3 - 4.5	4.5 - 6.0	23	-	-	-	-	-	-
FP- 5	0.7	0.0 - 1.2	1.2 - 2.6	2.6 - 3.6	52	-	-	-	-	-	-
FP- 6	1.0	0.0 - 3.0	3.0 - 3.2	3.2 - 3.8	24	-	-	-	-	-	-
FP- 7	1.3	0.0 - 1.1	1.1 - 4.5	4.5 - 5.1	25	-	-	-	-	-	-
FP- 8	1.0	0.0 - 0.9	0.9 - 1.5	1.5 - 2.0	32	-	-	-	-	-	-
FP- 9	1.2	0.0 - 0.8	0.8 - 1.4	1.4 - 2.5	50	-	-	-	-	-	-

LEGEND FOR GRAPHIC LOGS

FD-3	Foundation Test Boring
BD-2	Borrow Test Boring
28 SEPT 1960	Date exploration completed
El. - 14.1 M.S.L.	Elevation of ground surface at time of exploration
SP	Group letter symbol according to Unified Soil Classification System
10	Blows per foot of penetration considered most representative for each sample drive using a 350 pound hamer with a free fall of about 18 inches on a 1½" I.D. or 2" O.D. and/or 2" I.D. or 2½" O.D. size sample spoon equipped with a beveled and sharpened drive shoe
EL-55.8 M.S.L.	Elevation of bedrock surface
	Rock symbol
	Rock core recovery 0 - 25 %
	Rock core recovery 25 - 50 %
	Rock core recovery 50 - 75 %
	Rock core recovery 75 - 90 %
	Rock core recovery 90 - 100 %



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

HURRICANE SURVEY
WAREHAM - MARION, MASS.
WAREHAM RIVER & WEWEANTIC RIVER BARRIERS
GEOLOGY
PLAN AND RECORD OF EXPLORATIONS

DES. BY C.G.H. | DR. BY R.A.W. | CK. BY R.C.G.

SUBMITTED: HEAD, GEOLOGY SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED: ACTG CHIEF, FDN & MAT'LS BRANCH
APPROVAL RECOMMENDED: CHIEF, PLANN. & PT'S BRANCH
APPROVED: CHIEF, ENGINEERING DIVISION

DATE JUNE 1961

SCALE AS SHOWN

TO ACCOMPANY REPORT DATED 25 OCT. 1961

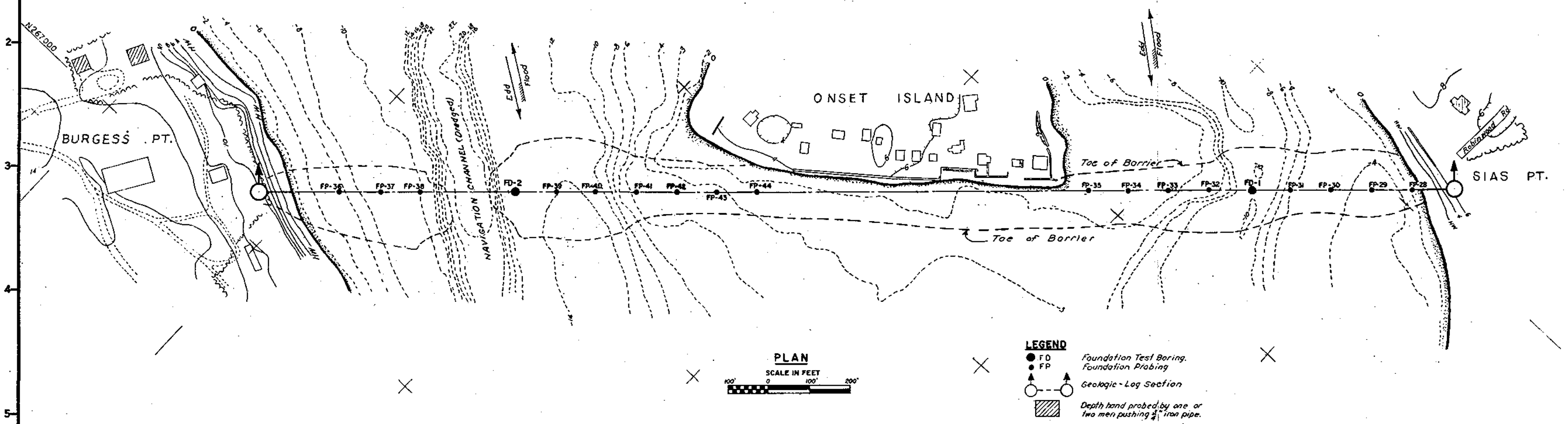
DRAWING NUMBER WMM - 2 - 1000

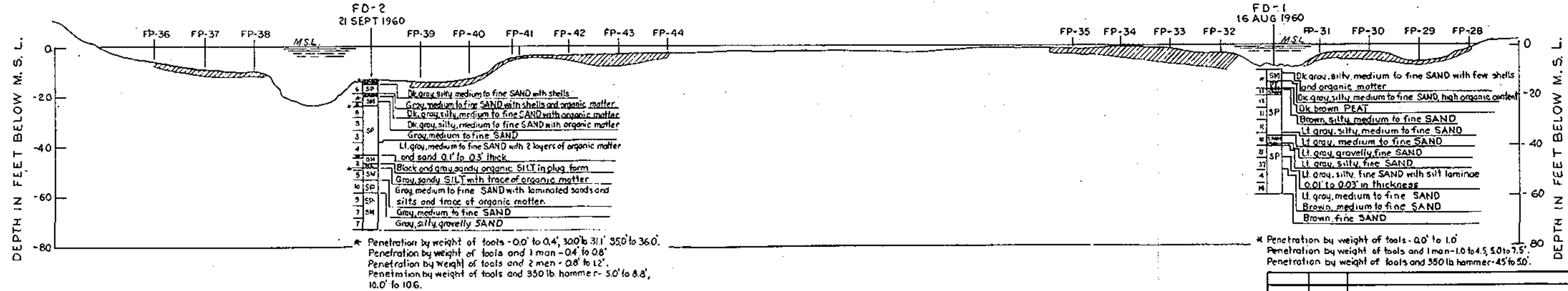
SHEET

CORPS OF ENGINEERS U. S. ARMY

PROBING TABLE

PROBING NUMBER	CORRECTED SOUNDINGS (MSL)	PENETRATION DEPTH (1 MAN)	PENETRATION DEPTH (2 MEN)	PENETRATION DEPTH AND BLOWS/FT. REQ. (8# HAMMER)			
FP-28	1.3 (FEET)	0.0-0.7	0.7-1.9	1.9-4.9	22	31	41
FP-29	6.1	0.0-2.0	2.0-2.2	2.2-4.0	21	35	-
FP-30	2.9	0.0-3.7	—	3.7-5.2	17	35	-
FP-31	3.5	0.0-1.0	1.0-2.3	2.8-4.8	22	19	-
FP-32	4.3	0.0-5.0	5.0-5.4	5.4-7.4	16	14	-
FP-33	1.6	—	0.2-5.9	5.9-7.9	15	17	-
FP-34	0.5	0.0-0.9	0.9-4.1	4.1-7.1	13	14	13
FP-35	1.1	0.0-0.7	0.7-2.1	2.1-5.1	31	19	18
FP-36	5.9	0.0-2.1	2.1-2.2	2.2-4.2	25	24	-
FP-37	9.2	0.0-1.8	1.8-2.7	2.7-3.7	27	-	-
FP-38	9.8	0.0-0.5	0.5-1.9	1.9-2.9	25	-	-
FP-39	13.8	0.0-1.3	1.3-2.4	2.4-3.4	23	-	-
FP-40	13.3	0.0-0.7	0.7-1.8	1.8-2.8	21	-	-
FP-41	3.5	0.0-1.0	1.0-1.3	1.3-4.3	23	20	28
FP-42	3.2	0.0-1.6	1.6-1.9	1.9-4.9	15	13	18
FP-43	3.1	0.0-0.6	0.6-5.0	5.0-6.0	25	-	-
FP-44	2.5	0.0-1.6	1.6-2.0	2.0-3.0	24	-	-





GEOLOGIC - LOG SECTION

(LOOKING NORTHWEST)

NOTES

Contours are in Feet
All elevations refer to Mean Sea Level
Grid system is based on Massachusetts State Plane Coordinates.
See Plate D-6 for Legend for Graphic Logs.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY C.G.H | DR. BY R.A.W. | CK. BY R.C.G.

SUBMITTED: R.C. Gurley, HEAD, GEOLOGY SECTION
PROJECT ENGINEER: D.G. Hendrickson
APPROVAL RECOMMENDED: ACTG CHIEF, FDN & MAT'LS BRANCH
APPROVAL RECOMMENDED: CHIEF, PLANNING & R'PTS BRANCH
APPROVED: CHIEF, ENGINEERING DIVISION

HURRICANE SURVEY

WAREHAM - MARION, MASS.

ONSET BAY BARRIER
GEOLOGY
PLAN AND GEOLOGIC-LOG SECTION

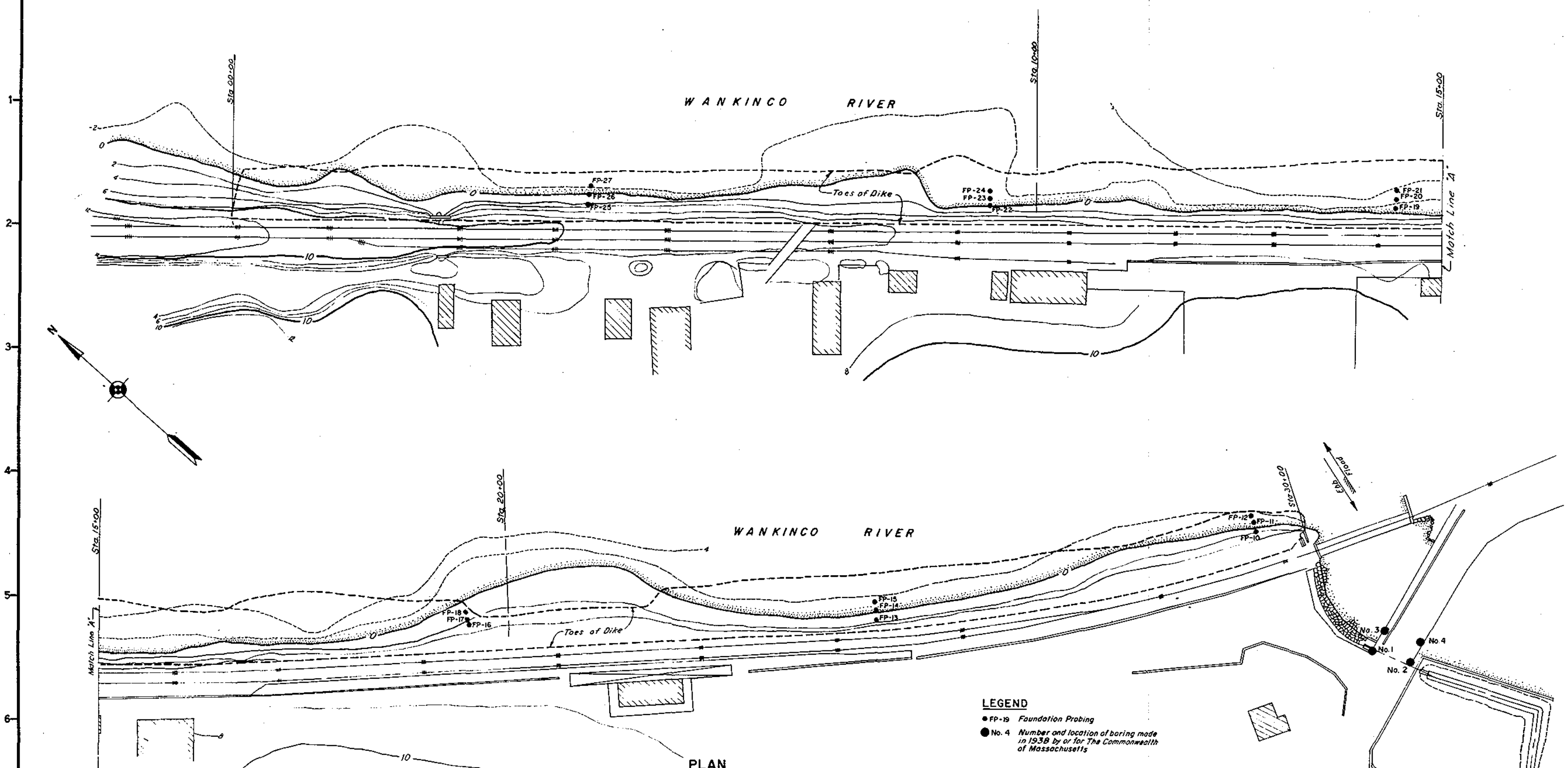
DATE JUNE 1961

SCALE: AS SHOWN | SPEC. NO. ENG-19-016-

TO ACCOMPANY REPORT DATED 25 OCT. 1961

DRAWING NUMBER WMM - 2 - 1001
SHEET

CORPS OF ENGINEERS | U. S. ARMY



LEGEND

• FP-19 *Foundation Probing*

● No. 4 *Number and location of boring made in 1938 by or for The Commonwealth of Massachusetts*

NOTES

All elevations refer to Mean Sea Level.
Contours are in feet.

PLAN

SCALE IN FEET

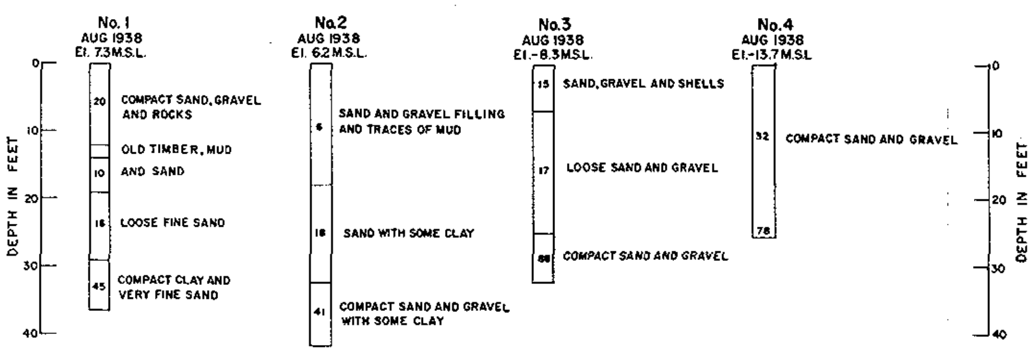
50' 0 50' 100'

PROBING TABLE

PROBING NUMBER	CORRECTED SOUNDINGS (M.S.L.)	PENETRATION DEPTH (1 MAN)	PENETRATION DEPTH (2 MEN)	PENETRATION DEPTH AND BLOWS/FT. REQ. (18 LB. HAMMER)							
FP-10	+0.5 FEET	—	—	0.0-7.0	14	17	11	17	9	8	11
FP-11	1.0	—	—	0.0-6.0	26	8	6	7	19	17	-
FP-12	3.0	0.0-0.8	—	0.5-5.0	11/5	4	4	10	11	-	-
FP-13	0.8	—	—	0.0-6.0	5	13	14	28	20	36	-
FP-14	0.7	0.0-1.1	1.1-1.3	1.3-6.0	12/7	13	16	24	28	-	-
FP-15	1.4	0.0-0.4	0.4-3.1	3.1-6.0	24/9	25	23	-	-	-	-
FP-16	+1.1	0.0-1.2	1.2-1.4	1.4-7.0	3/6	3	7	24	20	13	22
FP-17	1.4	0.0-2.0	2.0-2.1	2.1-3.2	15/9	60/2	-	-	-	-	-
FP-18	0.5	0.0-0.7	—	0.7-5.0	15/3	38	19	53	48	-	-
FP-19	0.0	0.8-1.3	—	0.0-0.8	13/8	-	-	-	-	-	-
				1.3-7.0	9/7	9	14	13		30	32
FP-20	1.6	0.0-3.5	—	3.5-6.0	20/5	49	32	-	-	-	-
FP-21	2.7	0.0-2.8	—	2.8-4.0	31/2	42	-	-	-	-	-
FP-22	0.2	0.0-0.2	7.0-12.7	0.2-7.0	4/8	5	3	6	5	4	6
				12.7-13.1	25/4	-	-	-	-	-	-
FP-23	2.1	0.0-10.0	—	10.0-11.2	26	33/2	-	-	-	-	-
FP-24	2.0	0.0-10.9	—	10.9-11.3	42/4	-	-	-	-	-	-
FP-25	0.1	—	—	0.0-4.7	10	5	3	4	50/7	-	-
FP-26	1.8	0.0-1.7	—	1.7-3.4	7/3	15	50/4	-	-	-	-
FP-27	2.6	0.0-1.8	1.8-2.9	2.9-4.0	5/1	70	-	-	-	-	-

NOTE

Fractional foot of penetration indicated as follows: number of blows / tenths of a foot. (25/5).



NOTE

The terminology used to describe the soils does not conform with the Unified Soil Classification System.
Figures in columns indicate blows per foot on spoon.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY C.G.H. | DR. BY R.A.W. | CK. BY R.C.C.

SUBMITTED — HEAD, GEOLOGY SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED — ACTG. CHIEF, FDN. & MAT'LS BRANCH
APPROVAL RECOMMENDED — CHIEF, PLANN. & OP'TS BRANCH
APPROVED — CHIEF, ENGINEERING DIVISION

HURRICANE SURVEY
WAREHAM - MARION, MASS.
BUSINESS CENTER DIKE
GEOLOGY
PLAN AND RECORD OF EXPLORATIONS

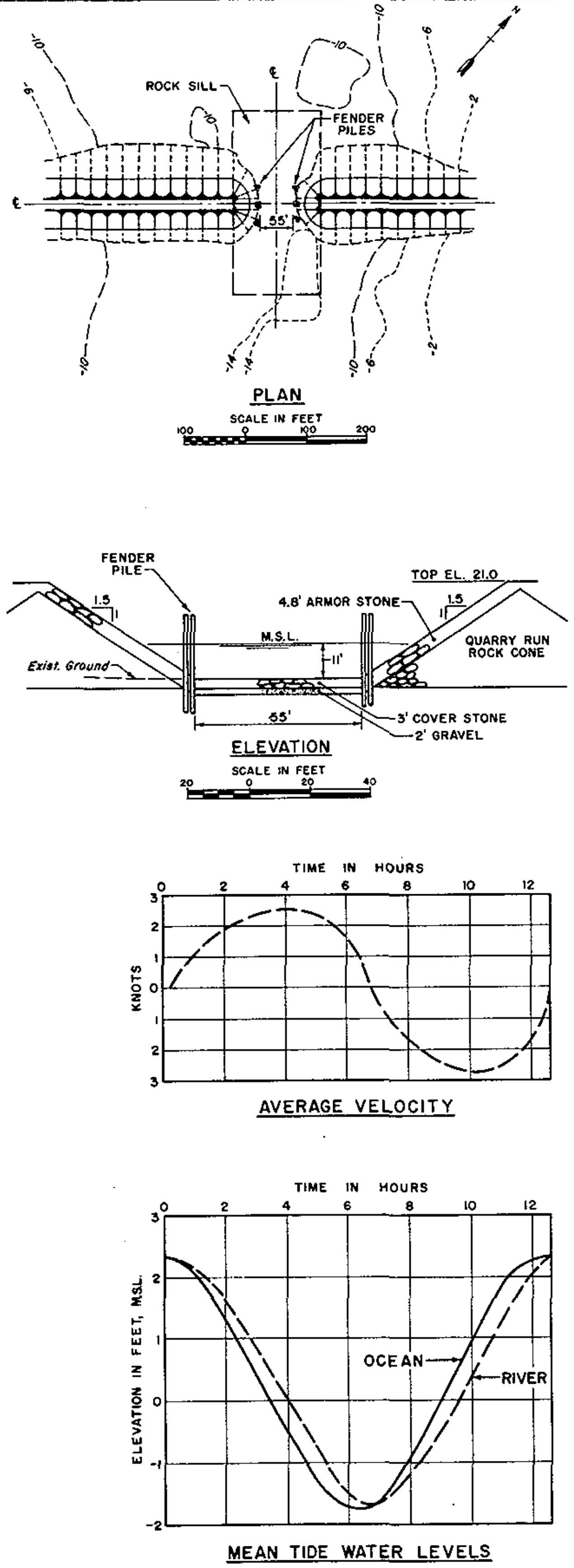
DATE JUNE 1961

SCALE AS SHOWN | SPEC. NO. ENG-19-016-

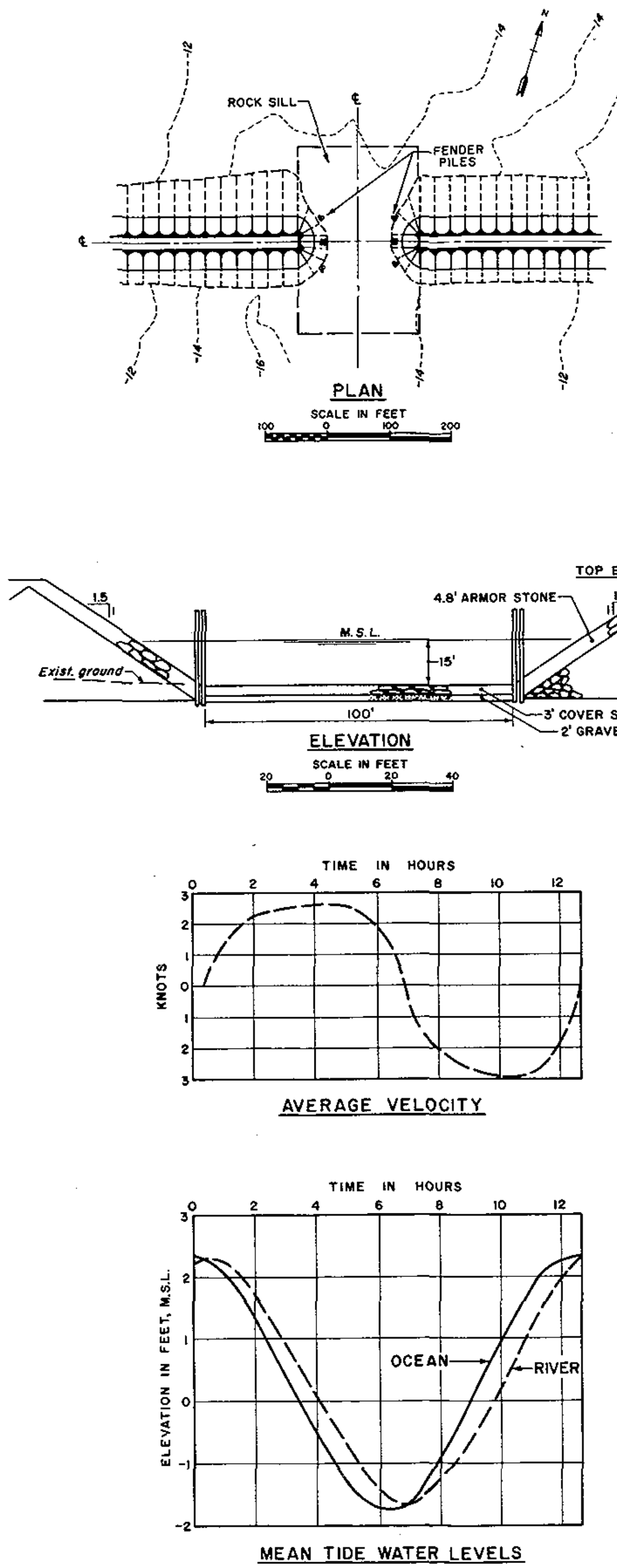
DRAWING NUMBER WMM - 2 - 1002

SHEET

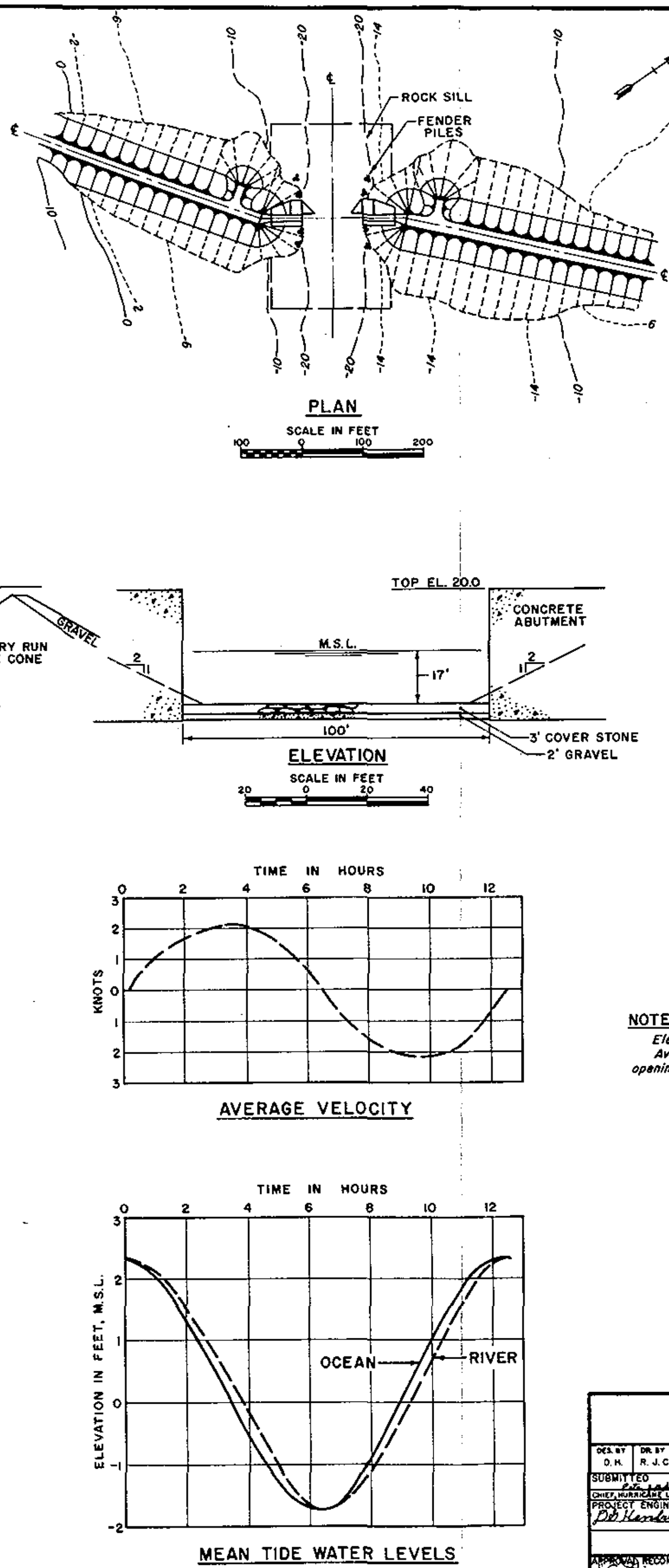
TO ACCOMPANY REPORT DATED 25 OCT. 1961



WEWEANTIC RIVER



WAREHAM RIVER



ONSET BAY

NOTES:

Elevations are in feet and are referred to mean sea level.
Average velocities are based on minimum area of navigation opening.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY
D.H.	R.J.C.	D.H.

SUBMITTED
CHIEF, HURRICANE UNIT NO. 2
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, PLANN. & RPTS. BRANCH
APPROVED
CHIEF, ENGINEERING DIV.

HURRICANE SURVEY
WAREHAM - MARION, MASS.
WEWEANTIC, WAREHAM & ONSET BAY
NAVIGATION OPENINGS
AVERAGE VELOCITY & MEAN TIDE LEVELS

DATE OCT. 1961
SCALE AS SHOWN
DRAWING NUMBER
WMM - I - 1007
SHEET

TO ACCOMPANY REPORT
DATED 25 OCT. 1961

APPENDIX E

LETTERS OF COMMENT AND CONCURRENCE

APPENDIX E

LETTERS OF COMMENT AND CONCURRENCE

Exhibit No.	Agency	Letter dated
E-1	The Commonwealth of Massachusetts, Water Resources Commission	14 June 1960
E-2	The Commonwealth of Massachusetts, Water Resources Commission	9 August 1960
E-3	Governor, Commonwealth of Massachusetts	17 April 1961
E-4	Office of Board of Selectmen, Wareham, Massachusetts	3 March 1961
E-5	Chairman, Board of Selectmen, Marion, Massachusetts	11 October 1960
E-6	Chairman, Board of Selectmen, Marion, Massachusetts	16 March 1961
E-7	U.S. Department of Health, Education, and Welfare, Public Health Service	21 June 1960
E-8	U.S. Department of the Interior, Fish and Wildlife Service	13 June 1961

OFFICE OF THE DIRECTOR

The Commonwealth of Massachusetts

Water Resources Commission

73 Tremont Street, Boston 8

June 14, 1960

Colonel Karl F. Eklund
Deputy Division Engineer
U. S. Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

RE: Proposed Hurricane Protection for Wareham, Massachusetts

Dear Colonel Eklund:

This office is in receipt of your letter of May 12, 1960, containing the results of the preliminary study for providing hurricane protection for the town of Wareham, Massachusetts. It is proposed to construct barriers with ungated navigation openings across the Weweantic River, the Wareham River, and Onset Bay, including barrier dikes to obtain closure.

In order to ascertain the effects upon fish and wildlife, pollution control, and navigation, this Commission contacted the State agencies having these specific responsibilities; namely, the Division of Marine Fisheries, the Division of Fisheries and Game, the Division of Waterways of the Department of Public Works, and the Department of Public Health (the State Water Pollution Control Agency). The comments from those agencies can be summarized that the proposed project is needed for hurricane protection in the area and that the project would not have an adverse effect upon fish and wildlife, navigation, or the pollution problem.

One agency pointed out that barriers of the type proposed might become attractive to marine sportsfishermen as sites for shore fishing. This would give additional value to the project, particularly if the barriers were constructed in such a way so that foot travel could be facilitated on top of the barriers.

Accordingly, the Water Resources Commission, at its meeting on June 13, 1960, recognized the value and urgent need of the proposed project for hurricane protection in the Town of Wareham and gave provisional approval to the preliminary project pending the submission of final plans.

The Commission hopes that this badly needed project can be expedited.

Sincerely yours,

C. I. Sterling Jr.

Clarence I. Sterling, Jr.
Director and Chief Engineer

CIS/n

The Commonwealth of Massachusetts
Water Resources Commission
OFFICE OF THE DIRECTOR
73 Tremont Street, Boston 8

August 9, 1960

John W. Leslie, Chief
Engineering Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

RE: Affect of Wareham Hurricane Protection Works Upon Shellfish Propagation.

Dear Mr. Leslie:

This office is in receipt of your letter of July 14, 1960, requesting the views and comments of the Commonwealth in regard to possible damage to shellfish in the Wareham and the Weweantic rivers should hurricane barriers be constructed across these two rivers.

Under date of June 14, 1960, the Commission sent a letter to Colonel Karl F. Eklund giving the comments of the various State agencies in regard to this project. However, upon receipt of your letter, a further survey was requested of the State Division of Marine Fisheries. That Division made another study of the matter and their report shows that it is very difficult to predict effectively what would happen to shellfish life by modifying natural environmental conditions.

They pointed out that these barriers might cause a reduction in salinities above the barriers during periods of heavy runoff but it was felt that, in view of the fact that oysters comprise ninety per cent of the shellfish in that area, the short temporary periods of low salinity should have no detrimental affect. If there should be a heavy increase in sedimentation, it would, however, have an adverse affect upon the shellfish populations.

The records of that Division show that there are no commercial shellfish permits issued in the Town of Marion and no commercial fishing is permitted in Buzzards Bay.

In view of this report, the Water Resources Commission, at its meeting on August 8, 1960, re-affirmed the endorsement contained in its letter of June 14, 1960, which gave provisional approval to the preliminary project pending the submission of final plans.

Sincerely yours,

C. I. Sterling Jr.

Clarence I. Sterling, Jr.
Director and Chief Engineer

Copy to Mr. Frederick C. Wilbour
Director of Marine Fisheries

CIS/n

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE DEPARTMENT
STATE HOUSE, BOSTON

JOHN A. VOLPE
GOVERNOR

April 17, 1961

Brig. Gen. Seymour A. Potter, Jr.
Division Engineer
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Dear Sir:

I have received your letter of March 3, 1961 outlining the report you plan to submit to Congress on the hurricane survey at Wareham and Marion, Massachusetts and requesting my opinion on the matter. It is my understanding that you propose recommending authorization of the project as shown on the map accompanying your letter.

The Town of Wareham will unquestionably derive tremendous benefits from the hurricane protection outlined for that town. Marion, on the other hand, will receive very little benefit, if any.

I have, of course, made inquiries into the reaction to the proposal on the part of all interests in the Communities affected, and after careful consideration, it is my wish to give the plan my endorsement in principle. My endorsement is based, in part, on the following:

1. It is my understanding that the Town of Marion will receive no assessment in connection with the project;

EXHIBIT E-3

2. It is my understanding that the Town of Wareham is willing to absorb the entire local community cost of the project; and

3. The formula for the state-local payments for the cost of the project, a matter for special legislation, will have to be decided once the project is authorized and plans drawn.

Sincerely,

John Volpe

Governor

Office of
Board of Selectmen
WAREHAM, MASS.

BENJAMIN A. MERRIHEW
JOHN B. ENGLISH
EDWIN H. MORSE

March 3, 1961

Seymour A. Potter, Jr.
Brigadier General, USA
U.S. Army Engineer Division
424 Trapelo Road
Waltham 54, Massachusetts

Dear Sir:

Reference is made to your letter of February 28, 1961 requesting comments on your considered hurricane protection plan for Wareham and Marion, Massachusetts.

The need for protection is great as evidenced by the fact that Wareham alone sustained damages of over $5,000,000 from tidal flooding in Hurricane "Carol" on April 31, 1954. Your proposed plan of protection by means of barriers across the Weweantic and Wareham Rivers and the entrance to Onset Harbor, together with supplemental dike protection, would serve to greatly reduce this loss in future hurricane experiences.

The Selectmen of Wareham believe that this project should be authorized by the Congress and its construction undertaken just as soon as possible. In taking this position, we recognize that the Town of Marion will probably continue to officially object to the location of any protection in Marion; namely, your Power Line Dike and the closure dike at the west end of the Weweantic River Barrier at Bass Point. We consider the construction of these works to be desirable in the interest of reducing heavy flood damages along the Wareham shore of the Weweantic River.

Further, it is our considered opinion, supported by the views of other town officials, that your recommended conditions of local cooperation will be met by the town, with assistance from the Commonwealth, when required prior to the construction of the project. We presently anticipate that no share in the requirements of local cooperation will be forthcoming from the town of Marion.

Yours very truly,

Benjamin A. Merrihew
John B. English
Edwin H. Morse
BOARD OF SELECTMEN

EXHIBIT E-4

THE TOWN OF
MARION, MASSACHUSETTS

October 11, 1960

Karl F. Eklund
Colonel, Corps of Engineers
Acting Division Engineer
424 Trapelo Road
Waltham 34, Mass.

Dear Colonel Eklund:

The Marion Board of Selectmen have no choice but to express the sentiments indicated at the hearing held by it on August 4, 1960, at which meeting residents resoundly recorded their opposition to approval of anchoring the west end of a Weweantic Hurricane Barrier on the locus in Marion endorsed by your engineers.

Those attending also showed no interest in a Barrier across Marion Harbor itself.

We wish to thank you for the courtesy of sending Messrs. Scott and Hendrickson to help us in our deliberations and trust that we will be fully advised of all progress in further planning for the protection of Wareham.

Very truly yours,

Russell Makepeace

Russell Makepeace, Chairman

Board of Selectmen,
Marion, Mass.

RM:j

EXHIBIT E-5

THE TOWN OF
MARION, MASSACHUSETTS

March 16, 1961

Brigadier General Seymour A. Potter Jr.
United States Engineer Division New England
Corps of Engineers
424 Trapelo Road
Waltham 54, Mass.

Dear Sir:

Your letter, dated March 1, 1961, to the Board of Selectmen is acknowledged. There has been no change in the local attitude since the Public Meeting of August 4, 1960, concerning the Weweantic River dike, nor the separate protection of Sippican Harbor.

We note from the map enclosed with your recent letter that your engineers are proposing two changes in the Weweantic project:

1. The westerly anchor of said dike will touch Marion south of "Bass Point".
2. The supplementary dike, originally placed north of Route 6 and east of Point Road has been moved westerly to the transmission line.

This would place the southeasterly end almost directly at the juncture of Point Road and Route 6. It would seem that some description of what is intended should be made known to us in order that any possible difficulties might be ironed out.

It is also apparent that the September, 1960 hurricane made no noticeable change in the thinking of the townspeople. We will be very happy to receive any comments made by the Commonwealth and the Town of Wareham in reply to similar letters.

Very truly yours,

BOARD OF SELECTMEN

Edward A. Briggs Jr.

Chairman

EXHIBIT E-6

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE

PUBLIC HEALTH SERVICE

REGION II
42 BROADWAY
NEW YORK 4, N. Y.

Refer to: 24: SE

June 21, 1960

U. S. Army Engineer Division,
New England
Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Attention: Colonel Karl F. Eklund
Deputy Divison Engineer

Dear Sir:

Reference is made to your letter of May 12, 1960, relative to the proposed hurricane protection works in the town of Wareham, Massachusetts.

We have reviewed your proposal to construct hurricane barriers as shown on the U. S. Army Engineer Division, New England, Hurricane Survey, Wareham, Massachusetts General Plan, dated April 1960 and revised May 3, 1960, with the Massachusetts Department of Public Health and from the information available, it does not appear that the proposed hurricane protection works will have any adverse affect on their water supply, water pollution control or vector control programs.

For the Regional Engineer.

Sincerely yours,

L. M. Klashman EA

Lester M. Klashman
Regional Program Director,
Water Supply & Pollution Control

EXHIBIT E-7

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

June 13, 1961

Division Engineer
New England Division
U. S. Army, Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Dear Sir:

This is our conservation and development report on the fish and wildlife resources relative to the Wareham-Marion, Massachusetts Hurricane Protection project. This report has been prepared in cooperation with the Massachusetts Division of Fisheries and Game and the Massachusetts Division of Marine Fisheries, and has their concurrence.

In general, the protection plan consists of barriers with ungated navigation openings across the Weweantic River at a point about 1,500 feet above its mouth; across the mouth of Wareham River in the vicinity of Nobska Point; and across the entrance to Onset Bay from Burgess Point to Sears Point. A dike is planned along Point Road in Marion, Massachusetts between County Road and Wareham Road. Several short dikes would close low areas along Great Neck Road in Wareham. A dike is proposed also along the west bank of the Wareham River for protection of the business district. This dike would be built in conjunction with the Wareham River barrier and would provide increased protection to the business district, over that provided by the Wareham River barrier alone. It is our understanding that if local interests so desire, the barrier across the Wareham River could be built alone or in conjunction with either the Onset Bay barrier or the Weweantic River barrier.

The navigation openings are sized to allow normal tides through the opening with a minor reduction in tidal range. The maximum average velocities through navigation openings would be 3 knots or less, and the reduction in tidal range about 0.2-foot.

The proposed barriers will be geographically situated in areas of biological significance. These areas, referred to as estuarine regions, are vital in promoting the maintenance of marine life. The rhythmic interchange of tidal salt water from the sea and freshwater runoff from the upland creates a restrictive environment which, to certain species of fish and wildlife, is necessary during a portion of or throughout their entire life span. This delicately balanced salt- and freshwater habitat exists in lower portions of the Weweantic River, the Wareham River, and in Onset Bay.

Outstanding fin-fishery resources are found in the project area. The following fish species are sufficiently abundant in Buzzards Bay to constitute an excellent sport fishery: black sea bass, striped bass, bluefish, Atlantic bonito, Atlantic cod, summer flounder, winter flounder, northern kingfish, Atlantic mackerel, pollock, scup, American shad, Atlantic smelt, weakfish, tautog, Atlantic tomcod, and white perch. These estuarine regions serve as a spawning or nursery area for many species of sport and commercial fish, including: winter flounder, American shad, Atlantic smelt, weakfish, scup, white perch, black sea bass, tautog, Atlantic herring, Atlantic menhaden, alewife, cunner, butterfish, northern puffer, and bluefish, as well as many species of baitfish. Undoubtedly, one of the reasons why these regions are such productive fishing areas is that predaceous fish species, such as striped bass and bluefish, find an abundant supply of food in these waters.

Shellfish resources of significant value are also found in the project area. A variety of conditions such as favorable salinity, bottom types, oxygen concentrations, tidal fluctuations, parent stocks, temperatures, and other factors are necessary to support setting, survival, and growth of shellfish species. These favorable factors exist in the Weweantic River, Wareham River, and in Onset Bay; for although shellfish stocks fluctuate from year to year, these areas are productive of oysters, soft clams, quahogs (hard clams) and bay scallops. For example:

1. In the estuarine area above the location of the proposed barrier on the Weweantic River, it would be typical to harvest 200 bushels of oysters valued at \$3,000; 500 bushels of soft clams valued at \$7,500; 200 bushels of quahogs valued at \$1,600; and 1,500 bushels of bay scallops at a value of \$12,000. The total average annual value of shellfish to the fishermen would be approximately \$24,100 in the Weweantic River area.

2. The estuarine region inside the location of the proposed Wareham barrier would contain a typical harvest of 700 bushels of oysters valued at \$4,200; 500 bushels of soft clams valued at \$2,500; 3,000 bushels of quahogs valued at \$27,500; and 7,500 bushels of bay scallops valued at \$54,000. The total average annual value of shellfish to the fishermen would be approximately \$88,200 in the Wareham River area.

3. The estuarine area inside the location of the proposed Onset barrier would have a typical harvest of 500 bushels of oysters valued at \$3,000; 500 bushels of soft clams valued at \$2,500; 3,000 bushels of quahogs valued at \$27,500; and 7,000 bushels of bay scallops valued at \$50,000. The total average annual value of shellfish to the fishermen would be approximately \$83,000 in the Onset Bay area.

Although there will be annual fluctuations of shellfish populations and market prices at landings, our studies show that the average annual value of the shellfish resources in the project area is approximately \$195,300.

Waterfowl and shorebirds are dependent upon the wetlands and inter-tidal mudflats of the project area. Those wetlands of importance for waterfowl are:

1. The 256 acre wetland called the Weweantic River complex located above the proposed Weweantic barrier.

2. The Oakdale marshes - 117 acres; the Agawam River Marsh - 77 acres; Salt Marsh - 173 acres; Maple Swamp - 224 acres; and Marks Cove Marsh - 141 acres, which make a total of 732 acres of wetlands found above the proposed Wareham barrier.

3. The Point Richard marshes - 61 acres, and Broad Marsh - 64 acres, totaling 125 acres of wetlands located above the proposed Onset barrier.

Total wetland important for waterfowl in the project area amounts to 1,113 acres. The wetlands with their accompanying tidal mudflats contribute to the maintenance of Atlantic Flyway waterfowl as they migrate between the nesting grounds to the north and wintering grounds to the south in spring and fall seasons. Wetlands are used extensively by shorebirds and other water-associated birds such as herons and bitterns.

We have determined from our studies that the fish and wildlife resources of the project area have value of outstanding proportions, but it has been difficult to evaluate the over-all effect that a minor reduction in tidal range might have upon the resources of the project. We conclude, however, that with consideration for the minor reduction in tidal range, the actual construction of the dikes and barriers, and problems of non-tidal drift associated with pollution factors, there would be no significant adverse effects on the wildlife and finfish resources as a result of the project.

While we anticipate at this time that there will be negligible effects on local shellfish populations, the possibility should be noted that the effects of reduced tidal flows, possible silting, and salinity changes may eventually alter the habitat upstream from the barriers to where it will be much less favorable for shellfish production.

We conclude, also, that in an area so rich in sport-fishery resources, consideration should be given to land-based fishermen from the standpoint of access and parking facilities related to the proposed barriers. Here is an opportunity to provide maximum project use through the coordinated efforts of your agency, the Massachusetts Division of Fisheries and Game, and this Service with regard to possible minor modifications in barrier plans during the design planning stages.

Therefore, we recommend--

1. That access and parking facilities for land-based fishermen be considered as possible minor modifications in barrier plans during the design planning stage.

2. That the development of access and parking facility features be coordinated with the Massachusetts Division of Fisheries and Game and this Service.

It is anticipated that additional studies by this Service will not be necessary. However, we should be informed of any change in project developments so that we can make additional comments.

The opportunity to report on this project is much appreciated.

Sincerely yours,

John S. Gottschalk
Regional Director
Bureau of Sport Fisheries & Wildlife

Russell T. Norris
Acting Regional Director
Bureau of Commercial Fisheries